COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF HIGHWAYS

HANDBOOK for INSPECTORS

HARRISBURG, PA.

JANUARY, 1964

EXCAVATION

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CHAPTER I

ORGANIZATION OF PENNSYLVANIA DEPARTMENT OF HIGHWAYS

Members of Engineering Staff

1. The Pennsylvania Department of Highways employs many men who are concerned directly with the construction of highways. Each of these men has a job to do. Of course, he is expected to do his own work right. If he is in charge of other men, he must also see to it that each of them does his work properly. After he has done work, or has had work done, he may be required to report the results of that work to the man above him.

The man in charge of all engineering matters for the whole Department is the Chief Engineer, whose office is in Harrisburg. The State is divided into a number of Districts headed by a District Engineer.

Also, there is a Highway Department Laboratory in Harrisburg. The man in charge of this laboratory is called the Director of Research and Testing.

In each District there are the following men:

Assistant District Engineer(s)
District Construction Engineer
District Maintenance Engineer
District Bridge Engineer
District Roadside-Development Engineer
District Right-of-Way Engineer
District Soils Engineer
District Plans Engineer
District Traffic Engineer
District Safety Advisor
District Chief of Surveys

Also, in each District there is a District Materials Engineer, who reports to the Director of the Bureau of Material Testing and Research.

Each District Construction Engineer has under him a staff of Assistant District Construction Engineers, the number depending on the size of the District, "Inspectors-in-Charge" of projects, and a large number of Inspectors.

District Engineer and Assistant

2. The District Engineer is in charge of all work done in his District, including design; construction; maintenance; right-of-way; permits; traffic control; State aid to a local agency; and safety precautions. He must make certain that the work on each project is done in accordance with the Special Provisions of the Proposal for the project, the Contract Drawings prepared for the project, and the Specifications, which apply to

all projects in Pennsylvania. He cannot make any changes in these documents. The Chief Engineer is the only person who can.

The District Engineer advises the Director of Research and Testing whether or not suitable aggregates can be obtained from sources in the District and whether or not the required concrete or asphalt mixtures can be produced by local plants.

<u>District Construction Engineer</u>

3. The District Construction Engineer has charge of handling engineering details on Contract construction work. He gives instructions to the Assistant Construction Engineers and Inspectors-in-Charge. He watches the progress of the work to make sure that these instructions are followed and that the work meets all requirements. He also arranges meetings with the Contractor and representatives of public-utility companies and municipalities to discuss details of the project before work is started.

Right after a job is started, and from time to time, the District Construction Engineer goes over the job with the Assistant District Construction Engineer and the Inspector-in-Charge. Usually the Contractor or his representative goes along. On each such visit the District Construction Engineer observes the Contractor's methods of carrying on the work. He and the District Safety Advisor must make certain that the Contractor provides safe working conditions for Department employees. He has to approve all the estimates prepared by the Assistant District Construction Engineers.

Either the District Construction Engineer or the Assistant District Construction Engineer must collect and verify all the estimates of work done in the field. No other person can do this unless the District Engineer personally orders him to do so.

The District Construction Engineer notes the condition of each detour and sees that all signs are in good condition. If anything is wrong, he discusses the matter with the District Traffic Engineer.

<u>District Bridge Engineer</u>

4. The District Bridge Engineer inspects the foundations for bridges. His recommendations are first signed by the District Engineer and then sent to the Chief Engineer for final approval. The Bridge Engineer acts as a consultant to the Assistant Construction Engineers on special problems, and must be familiar with all the work done by Department forces on bridge design and construction. He checks all requests for the purchase of materials for bridges before they go to the Chief Engineer. He also has charge of design and office work on bridges and various other structures.

<u>District Soils Engineer</u>

5. The District Soils Engineer handles all problems relating to soil conditions. He must know a great deal about soils and how they affect the building of a highway. He is consulted on all earth construction,

the control of the water table by drainage, the prevention of slides, and the preparation of foundations in connection with either the design or the construction of the highway.

The District Soils Engineer has charge of all soil surveys and sampling. He prepares soil profiles for projects or reviews those prepared by a Consulting Engineer. If necessary, he recommends special design features or treatment pertaining to the subbase, the subgrade, or the shoulders. During construction, he advises the Inspectors on the job about the compaction and control of the embankment and subgrade materials.

District Safety Advisor

6. The District Safety Advisor see to it that all Department employees have safe working conditions.

In the company of the District Construction Engineer, the District Safety Advisor makes inspections of projects to be certain that the Contractor provides safe working conditions for Department employees. If a possible danger is noticed, it is brought to the attention of the Contractor by the District Construction Engineer.

The District Safety Advisor must investigate any personal injury suffered by a Department employee while working on the job, and must process all forms pertaining to it. He also reviews and gives advice on matters which apply to safety on Department maintenance work or on Contract construction.

District Chief of Surveys

7. The District Chief of Surveys is in charge of all survey work, including preliminary surveys and construction roadway and bridge stake-out. He must see to it that this work is done within the time allowed. He must make certain that the work is accurate and complete.

District Materials Engineer

8. The Highway Department Laboratory in Harrisburg is responsible for the quality of all materials used in construction. Representatives of the Laboratory inspect and test many materials, such as portland cement and asphalt, at the source of supply. Where materials are tested at the plant or field laboratory, a representative at the Department Laboratory makes check tests on duplicate samples. This comparison of test results is necessary to make sure that field tests are up to Laboratory standards. The Laboratory also tests all random samples. These samples are usually taken after the materials have been incorporated in the work. Provisions are also made for obtaining samples of some raw materials as they are being used where it is not possible or practical to obtain samples from the completed work. From the results of these tests on random samples, it can be determined how effective the routine project control has been in ensuring that all materials have been produced and used in compliance with the Specifications.

A District Materials Engineer represents the Department Laboratory in each District. He works with other representatives of the Laboratory assigned to the District Office, and gives them instructions on the control of the materials used for construction and maintenance. He usually has charge of checking aggregates from new sources and checking those from previously approved sources to make sure that they continue to meet the Specifications. The District Materials Engineer cooperates with the District Construction Engineer and the District Maintenance Engineer in making preliminary inspections of plants producing ready-mixed concrete or bituminous concrete. He is in charge of the inspection of plants where prestressed concrete beams are cast.

It is the duty of the District Materials Engineer to see to it that the District Office is prepared to control the quality and use of construction materials. If there is anything wrong with the method of sampling, testing, or using materials, he must inform the District Engineer, and offer suggestions for making the necessary corrections. He works with the District Engineer in designing portland-cement concrete and asphalt paving mixes.

The District Materials Engineer helps the District Engineer in setting up schools for the Inspectors and Resident Engineers. He also takes part in training programs, both on the job and in the District schools.

Assistant District Construction Engineer

9.. An Assistant District Construction Engineer has charge of construction on several projects. He must be familiar with the Proposals, Contract Drawings, and Specifications for these projects, and must keep in close touch with the work. If any changes in the Drawings or Special Provisions are necessary, he will inform the District Construction Engineer, who can ask the District Engineer to have the changes made by the Chief Engineer.

The Assistant District Construction Engineer must check lines and grades wherever they appear to be wrong. He must see to it that all materials are sampled and inspected properly and that samples are forwarded to the Laboratory without delay. He must instruct the Inspector-in-Charge on a project, check the details of the work with him, and review his records. He collects the estimates on which payments to the Contractor are based. He is personally responsible for the accuracy of all quantities submitted by him on current or semifinal estimates, except those relating to excavation and pavement.

Inspector-in-Charge

10. The Inspector-in-Charge of a project is responsible for all inspection work on a project, including inspection work necessary at plants for producing concrete. He must tell the Inspectors under him what to do and how to do the work. He must check to see that they are on the job and are carrying out his instructions. He must check their reports and be certain that they are right. He must see to it that all materials are sampled and tested properly, and that the samples taken in the field are forwarded to the Laboratory promptly.

When a property owner asks how the project will affect his property, the Inspector-in-Charge explains. The Inspector-in-Charge does not discuss damages or refer to the amount of money the property owner will get. Such information is given by the District Right-of-Way Engineer. The Inspector-in-Charge must warn the Contractor not to trespass or do any work on private property unless he has permission in writing from the property owner. If the Inspector-in-Charge finds that a structure or slope will extend beyond the right-of-way limit, he must report the fact to the Assistant Construction Engineer before construction is started. He must also report any condition that will require more work or material than called for in the Contract.

When a detour will be needed, the Inspector-in-Charge must report the need at least two weeks in advance to the District Engineer after being notified by the Contractor. He must see to it that the Contractor has enough flagmen to protect the work and direct traffic around it.

When the Inspector-in-Charge is notified that special cost records are to be kept on work done by a public-utility company, he must learn the extent of this work and keep the records. The cost records for this work, unless it is done by a railroad company, are kept in the same way as those for Force-Account work. The Inspector-in-Charge must work with the Contractor and a representative of the public-utility company so that poles or structures can be removed or reset without delaying the project.

A record of what was actually done is very important on any project. The Inspector-in-Charge must keep a diary which contains all the important notes in the diaries of all the Inspectors who work under him. The diary for each day must show the important things that happened on the project during that day. Entries in the diary must be so complete that the diary may be used to help settle a claim by the Contractor. The diary must show what work was done, where it was done, how many men were on the job, and how much material and what equipment were used, and the weather conditions. When any work is completed, its dimensions must be measured accurately and recorded in separate books. These measurements are usually taken along certain lines shown on the plans, unless other instructions were given in writing.

Inspectors

11. The Inspectors and Assistant Inspectors are very important employees of the Department of Highways. Since they must be on the job or at the plant whenever work is being done, they are the only persons who can make sure that every ton of material and every foot of pavement meets the Specifications. No matter how carefully the Specifications are written, or how carefully the plans are drawn, only the Inspector on the job can see to it that the work is done properly. The Inspector must make sure that all materials used meet the requirements of the Specifications and Special Provisions of the Proposal. He must see to it that they are placed and finished so that the completed work is exactly as required by the Contract Drawings, Specifications, and changes authorized by the Chief Engineer.

If anything is wrong, the Inspector must try to have the defect corrected as soon as possible. He must be firm in requiring the Contractor to do the work in accordance with the Specifications at all times. If he has trouble in getting the Contractor to do the work right, he must report the fact at once to the Inspector-in-Charge.

The Inspector must be familiar with the contents of the Proposal, the Contract Drawings, and the Specifications for the project, and must understand what is wanted. He must know how to make a quick check to determine whether materials meet the Specifications. He must know what methods and equipment should be used to do the job right. He must know how to check the completed construction to find out if the work has been done in accordance with the Contract.

Each Inspector must keep a diary in which he records everything that pertains to his duties. He must record quantities of materials used and measurements of the amount of work done. He must make notes to show where the work was done, the number of men and the machines used by the Contractor, and the weather conditions.

In conducting himself and performing his work, the Inspector should always keep in mind the General Policies of the Department of Highways as described in Chapter III of this Manual.

District Roadside Development Engineer

12. The District Roadside Development Engineer is responsible for all matters pertaining to roadside development. Such work covers all seeding, mulching, planting, sodding and selective tree removal and trimming. In this connection, he prepares the drawings and treatment sheets for such work. He also reviews other construction drawings before they are submitted to the Central Office, in order to determine if the soil-slope gradient relationship is satisfactory from the standpoint of erosion control. He reviews incidental structures such as tree walls and stone or concrete slope walls in order to insure protection of valuable trees and the elimination of erosion.

He accompanies those making semi-final inspections of construction projects in all cases where roadside development is included in the prime contract for the purpose of determining if the prime contractor has provided satisfactory conditions for such work.

He exercises control of the materials and procedures required for roadside development in the District within the allowable limits of the specifications. He makes inspections and investigations with respect to the proper performance of all roadside work conducted both by Department forces and that by contract and submits such reports as are necessary for the satisfactory completion of the work.

CHAPTER II

CONSTRUCTION PROCEDURE

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Proposal

1. When the Department of Highways decides that a section of highway is to be built in a certain location, the Department prepares a form called a Proposal (Form 410). The purpose of the Proposal is to describe the project in enough detail to enable Contractors to estimate the approximate cost of the project. It also states how much time will be allowed for the completion of the work. Each Contractor who is interested in building the section of highway is invited to submit a bid by filling out a copy of the Proposal. In order that Contractors will know when a project is planned, the Department of Highways gives them notice by placing an Advertisement of Project in newspapers and engineering and technical periodicals, as required by State laws. The Advertisement describes the project in a general way and gives instructions for obtaining a Proposal and submitting a bid.

A Contractor who intends to submit a bid requests a copy of the Proposal from the Department of Highways. This Proposal contains the following information:

- (a) The exact place to which the Proposals must be delivered.
- (b) When and where the Proposals will be opened.
- (c) The location of the project.
- (d) An adequate description of the project.
- (e) The approximate quantities of work of various kinds to be done.
- (f) The approximate quantities of materials to be furnished (some items only).
- (g) The working time in which the project must be completed.
- (h) Reference to the controlling Specifications and Drawings.
- (i) Supplements or Special Requirements relating to items which involve departure from the Specifications or may not be covered by them.

All documents bound with or attached to the Proposal are essential parts of the Proposal; and Specifications, Drawings, and other documents referred to in the Proposal are considered parts of the Proposal whether attached to it or not.

A Contractor must show in his bid the estimated cost of doing the work. To compute this cost, he enters suitable values in a schedule in the Proposal. The values that are under his control are the unit or lump sum prices for the various items in the Contract. The unit price for a material is the price of a unit quantity of the material such as the bid price for excavating a cubic yard of unclassified excavation. Each approximate quantity of material is multiplied by the corresponding unit price, and the results are added together to give the total cost.

Preliminary Conferences

2. Before the Notice to Proceed is given for the project, the Contractor or his authorized representatives must meet with the District Engineer in the District Office and consult with him about existing conditions, materials, and all other arrangements for performing the work satisfactorily. The Contractor must also observe for himself, with the approved Drawings before him, all pertinent conditions relating to the project, including the status of rights-of-way, structures, drainage features, and obstructions to be removed or changed.

The District Engineer will discuss with the Contractor in what places and in what ways the work is to be undertaken. The force of men needed, the equipment and materials required, and the rate of progress necessary to complete the project within the time specified should usually be based on the plan of operations approved for the project on Form 476, Distribution of Working Time and Minimum Equipment Requirements. If the Contractor desires to do the work in accordance with a different plan of operations, a revised Form 476 may be required.

After the first conference has been held in the District Office, and before the Notice to Proceed is given, an initial conference should be held at the site of the project in accordance with Form 408. The Contractor or his authorized representative, accompanied by the District Engineer or his designated representative and those firms affected by the construction and with the approved Drawings before him, should observe for themselves all pertinent conditions relating to the project. The group should discuss the Contractor's plan of operation and such other pertinent matters as the status of the rights-of-way, structures, drainage conditions, obstructions to be removed, and utility lines to be adjusted, relocated, or reconstructed. Where there is a possibility of interference with service or damage to property of a utility or plant, the Contractor must make suitable arrangements with the owners of the utility or plant before any work is started. These arrangements will be subject to the approval of the District Engineer, and the Contractor must take the necessary precautions while working on the project not to interupt the services of the plant or utility.

Stake-Out for Construction

3. The District Engineer will furnish and place construction stakes, usually offset from the centerline of the proposed roadway. Also, he will furnish the Contractor with grade sheets showing the horizontal and vertical measurements from the offset stakes to the centerline and grade line of the roadway. Where the roadway surface is to be warped, enough stakes will be set to meet the requirements.

Where the highway is to be constructed on a grade of more than 4 percent, an offset stake will be set on each side of each designated grade point. Opposite stakes are usually so located that a straight line between them will pass through the grade point on the centerline.

The Department will also place slope stakes at the toes of embankment slopes and adjacent to the tops of cut slopes whenever these points are more than 6 feet vertically below or above the finished grade of the roadway. The survey corps will place these stakes in advance of the grading operations, in order that both the Inspector and the Contractor can check them carefully. Due allowance will be made for widened pavements or shoulders, gutters, rounding of slopes, or special side ditches shown on the Contract Drawings or indicated on the Department Standard Drawings.

The Department will place all necessary centerline stakes for bridges, culverts, and other structures, and also any additional stakes and markers that may be required for the control and guidance of the Contractor's operations.

The Contractor must furnish, at no expense to the Department, any additional stakes for the proper control and performance of the work, as well as all templates and other devices that may be required for forming or checking the finished surface. He must make it as easy as possible to check all lines, grades, and measurements established by him.

The Contractor will be held responsible for preserving all stakes and marks in their original positions. If any of the construction stakes or marks have been carelessly or willfully destroyed or disturbed by him, the cost of replacing them will be deducted from monies due him on the project.

Assignment of Inspection Personnel

4. The Contractor must perform his work under the observation of, and subject to the examination of, Department Engineers and Inspectors. He must carry out all work during the working hours of the day, unless specifically directed otherwise. Department inspection may extend to any part of the work, and to the preparation, fabrication, or manufacture of the materials to be used.

The Inspector-in-Charge is expected to keep the Assistant District Construction Engineer informed with regard to the progress of the work and the manner in which it is being done. He should also direct the Contractor's attention to any non-conformance with the Drawings or Specifications. He is not authorized to approve or accept any portion of the work, to issue instructions contrary to the Drawings and Specifications, or to act as a supervisor for the Contractor.

Additional inspectors, who have knowledge of the work under construction, will be assigned to the project to assist in various phases of inspection. An Inspector must avoid arbitrary action and must be fair and just in his relations with the Contractor. If a question arises in the performance of his duties, he must contact the Inspector-in-Charge of the project. Inspectors must not, under any conditions, issue orders directly to laborers or other workmen on the project.

Starting Work

5. The Contractor is expected to begin work on the project on the calendar date specified in the Notice to Proceed, and to complete the project within the time specified in the Contract. In no case can he begin work before the date the Contract is approved by the Attorney General. If the Contractor does any work or incurs any expense in connection with the project before he receives the Notice to Proceed, he does so on his own responsibility.

A Contractor may want to start work on a project before all obstructions are removed from the right-of-way, or while it is still necessary to do some work that is not the responsibility of the Contractor, in order to put the right-of-way in completely satisfactory condition for the Contractor's operations. In such a case, the Contractor furnishes the District Engineer with a letter agreeing to start the work under the existing conditions. This letter will free the State, the Department, or any other interested party from any claim in case additional costs or damages result from such conditions or delays caused by them. Otherwise, the Notice to Proceed will not be given to the Contractor until the right-of-way has been cleared and is in satisfactory condition for him to proceed without interruption.

Working Time

6. The Department will give the Contractor a Form 476, which deals with the Distribution of Working Time and Minimum Equipment Requirements. On this form will be shown the detailed schedule or plan of the estimated time it should take the Contractor to perform each of the various "controlling" operations on the project, and the total Contract working time allowed for the completion of all work. If the Contractor wants to do the work in accordance with a different plan of operations, he prepares a revised Form 476 for completing the project within the specified Contract working time. He should show in his revised form that the highway structures and pavement will be completed within the designated period or periods indicated on the original Form 476 prepared by the Department. Extension of any time period designated on the original schedule for the completion of a structure or pavement may defeat the intent of the original plan of operations. A delay possibly could prevent the completion of the item of work before the winter season begins or could create undesirable traffic conditions because of the necessity of using temporary routes or unpaved sections, which would have been eliminated by following the original plan.

A revised Form 476 must also show the number of hours per day during which the Contractor plans to do work. It must be signed by both the Contractor and the District Engineer, and is to be submitted to the Chief Engineer for his consideration and approval. The District Engineer will be notified when the Chief Engineer has made his decision. If the revision is approved, the District Engineer will be furnished with copies of the revised form.

In order that the work on each part of the project may be completed in accordance with the requirements of the Drawings and Specifications in the designated time, the Contractor must furnish the necessary forces of workmen, the materials,

and equipment. If the work falls behind schedule, the District Engineer will order the Contractor, in writing, to provide additional workmen, materials, or equipment and the Contractor must supply whatever is ordered. Also, in doing the work, the Contractor must take all necessary precautions to make it possible to complete the project in the Contract working time.

The Contractor will not be permitted to perform any work on the project on a Sunday or a legal holiday, unless written permission has been obtained from the District Engineer. This restriction will not apply to the repair or servicing of equipment, protection of the work, maintenance or protection of traffic, or the curing of concrete as required by Form 408.

The Contractor must so conduct his operations that the length of work under construction will not be greater than the length he can deal with efficiently and without too much inconvenience to the public.

To determine whether or not the Contractor is keeping up to the schedule, Form 476 should be used as a basis for reporting actual progress. The actual progress can then be more easily compared with the scheduled progress shown on the form.

Time Charges

7. The controlling operation at any specific time may be defined as that operation (or set of operations) which determines the progress of the project at that time; all other operations are then secondary or incidental. Generally speaking, the first major controlling operation on a standard roadway construction project without bridges and approaches will be Grading and Drainage. Construction of the Base Course, placing of the Surfacing, or some other major item of work will become the controlling operation only when the proper time and condition of the work for starting that operation are reached in accordance with the working-time analysis on Form 476. If the Grading-and-Drainage operation is behind schedule and the Contractor is not ready to start the next controlling operation at the time shown on Form 476, Grading and Drainage will continue to be the controlling operation until the Contractor can start on another phase of the work.

Where the project includes a bridge and approaches, with the bridge the major item of work, construction work on the bridge will generally be the controlling operation until it is completed. The next controlling operation will then be grading and paving of the approaches, unless the approved plan of procedure indicates that the approaches are to be completed while work is being done on the bridge.

In case progress on the controlling operation is slowed down because of inclement weather or other unsuitable conditions beyond the Contractor's control, the Contractor proceeds with minor items of work, the time to be charged against the Contract will be based only on work done on the controlling operation.

It may happen that the Grading-and-Drainage operation is up to schedule and the scheduled date for starting the Paving operation has passed, but the Contractor cannot proceed with the Paving operation. If the Paving operation is being delayed at such a time by weather conditions and not because of any fault of the Contractor, the Contractor continues to grade, the Paving operation is considered the controlling operation. The reason is that the

construction of the Base Course or the Surfacing will still require the scheduled amount of time for its completion, regardless of the progress of the grading. However, if grading work is still being done and the Contractor cannot start on the next controlling operation for some cause other than unfavorable weather conditions, then Grading and Drainage will continue to be the controlling operation until this work reaches the stage at which the next controlling operation can be started. If the grading work has been completed and the Contractor fails to proceed with the next controlling operation in accordance with Form 476, this next operation is generally considered the controlling operation. The kind of work actually performed and the time spent on it should then be recorded.

In any case, the approved Working-Time Analysis on Form 476 should be used as the basis for charging time to each controlling operation. Frequently, the Contractor may want to continue excavation or grading during the winter months while Grading is still the controlling operation. The recorded time charged against the Contract for such work should be proportional to the amount of grading accomplished. The scheduled rate of progress in either the original Form 476 or the approved revision must be used as a basis until the time is reached when Grading is no longer the controlling operation.

Inspector's Diary

8. Each Inspector must keep a diary for every operation. Also, a project diary, which is a composite diary, must be kept by the Inspector-in-Charge for the project. The Inspector's diary contains a day-by-day record of all significant events relating to the project. It shows how many man worked, what equipment was used, how much work was done, where the work was performed, and the prevailing weather conditions. It should also show any delays and the reasons for them. The Inspector's diary is often extremely important in determining whether or not a delay is within or beyond the control of the Contractor. For this reason, the entries in the diary must be complete and the notes must give all pertinent details. There have been cases where complete and adequate notes in the diary saved the Department large sums of money. On the other hand, lack of information in the diary has resulted in great losses.

The project diary, which is kept by the Inspector-in-Charge, gives the following information:

(a) Weather conditions, including the minimum and maximum temperatures for the 24-hour period.
(b) Number and classification of the workmen employed by the Contractor.
(c) Various types of equipment used on each operation and the number of hours each was in use.
(d) Factors affecting the progress of the work.
(e) Assignments given to the several Inspectors under the supervision of the Inspector-in-Charge.
(f) Unusual happenings involving employees or equipment.
(g) Visitors received on the project and persons spoken to.
(h) Conferences attended.
(i) Other significant happenings.

The Contractor is responsible for supplying whatever labor, equipment, and materials may be needed to complete the project in the Contract time. Under normal conditions, no adjustment of time can be granted for such reasons as the following: failure to provide the necessary labor and/or equipment; non-delivery of materials; breakdown of machinery; delay caused by the failure of a public-service company or other agency to remove or adjust an obstruction or structure located within the limits of the work. A time charge will be eliminated only if the delay is caused by some condition for which the Contractor is not responsible and if it is shown that the Contractor used every practicable means to meet the requirements but failed to do so through no fault of his own.

An Inspector does not always have enough information to judge whether or not a delay which has occurred was within or beyond the control of the Contractor. The Inspector's records and diary are the sources of information from which the District Engineer will obtain his data for making decisions in regard to the daily time charges or claims for delays in the Contractor's operations.

A person who is not directly representing the Department or the Contractor will not be given diary information without the consent of the District Engineer. The District Engineer will frequently review the working times recorded by the Inspector-in-Charge, in order to make sure that this information is not misleading or unjust to the Contractor. When a portion of a day is charged, a complete explanation must be given in the diary.

Starting Date in Contract

9. The Contractor is expected to perform all work covered by the Contract completely and in an acceptable manner in the time stated in the Contract. As soon as the District Engineer receives notice that the Contract has been executed, he must make sure that the Contractor has personally gone over the project, that the Contractor's method and schedule of work have been discussed and agreed upon, and that public and private structures or obstructions to the Contractor's operations have been removed or other satisfactory arrangements have been made. He will then forward the official Notice to Proceed to the Contractor.

The Notice to Proceed will authorize the Contractor to start work on the project, and the legal Contract time will be charged from a specified date. This date will be selected so as to give the Contractor a reasonable length of time to arrange to get the work started. The allowance is usually 10 days, unless otherwise specified in the Contract. Under normal conditions, the Contractor will not be permitted to start work in anticipation that the Contract will be executed.

In case the Contractor has decided to start work immediately after the Contract has been approved by the Attorney General and before he has received the Notice to Proceed, the Notice to Proceed that is forwarded to the Contractor shall show a date on which work should start. This date will be

the one on which charging of legal Contract time will start. If the Notice to Proceed has been sent to the Contractor and he gets permission from the District Engineer to start work prior to the date set in it for the starting of the Contract time, such starting of work will be considered as a waiver of that date. The District Engineer will then forward to the Contractor a corrected Notice to Proceed, setting the date of the actual starting of work as the date on which the charging of legal Contract time will be started.

Adjusting Time Charged

10. The charging of liquidated damages against the Contractor is based upon the legal Contract time charged. Extension or decrease of Contract time is given consideration on the basis of an increase or decrease in the work and/or material on items forming one or more controlling operations as set forth in Form 408. Adjustments of time charges and corresponding adjustments in the amount of liquidated damages may be made by the Chief Engineer in accordance with Form 408. It is necessary that extreme care be used in establishing the recorded time charges.

The legal Contract time charged for a certain operation does not always indicate the actual time used for that operation. Therefore, the actual items of work performed must be shown daily, in order that the rate of progress for the different classes of work may be established. The Inspector must record in his diary for each day the time during which weather conditions permitted work to be done on the major controlling operations in effect on that day. The time charged is to be expressed to the nearest quarter of a day. This recorded time may be used for estimating purposes or possibly to show the reason for recommending an extension of time.

The charged times shown on Form 4147, Time Charge Record, will be based on the actual work performed by the Contractor on the controlling operation or operations, and not on the estimated amounts shown on Form 476. For example, Form 476 may show that Grading would be the controlling operation until the 50th day; but the Contractor may possibly have completed enough work in 40 days to permit him to start his Paving operations and continue them without undue interruption. Paving would then be the controlling operation on the 41st day. On the other hand, if the Contractor had not proceeded far enough with the Grading at the end of the 50th day and could not start on the Paving operation until the end of the 60th day, Grading would be the controlling operation for the 60 days.

Form 476 will be used for reporting actual progress in comparison with the scheduled estimated progress shown on the form, in order to determine whether the Contractor is up to schedule and whether he has performed the quantity of work or reached the point at which his next operation is to become the controlling operation.

Where progress on the controlling operation is curtailed because of inclement weather or other unsuitable conditions beyond the Contractor's control, and the Contractor proceeds with minor items of work, the time charged will be based only on the controlling operation.

Record of Time Charged

11. In order that the Contractor may be fully informed and have an accurate record of the time charged to each controlling operation, the Inspector-in-Charge will have the Contractor's authorized representative approve the time charged for each week. Also, the District Engineer must let the Contractor know in writing, as soon as possible after the end of a calendar month, how many working days were charged during the preceding month and how many working days have been charged altogether during the entire Contract time up to the end of that month.

When preparing his monthly report, the District Engineer should count only the time that is justly chargeable against each controlling operation on which work was done. The reported time should include, however, any periods for which adjustments may have been claimed by the Contractor. If the District Engineer and the Contractor cannot agree on the time that should be charged, the District Engineer will forward to the Chief Engineer the monthly report of time charges, together with a statement relating to the Contractor's claims for adjustments of time. The District Engineer will also include his own recommendations in regard to the Contractor's claims. The Chief Engineer will make his decision promptly and will give the District Engineer the necessary instructions.

Weekly Construction Reports

12. The District Office and the Central Office are kept informed on the status of the project by means of weekly construction reports, which indicate the amount of work performed on each of the major items. When the progress of a project shown on Form 476-E, Weekly Progress Graph, falls below 100 percent of the scheduled progress, the Inspector-in-Charge will notify the Contractor that this condition exists and that the progress of the project should show improvement. Failure of the Contractor to show immediate improvement in progress must then be called to the attention of the District Engineer. If the progress on any major item of work falls below 90 percent of scheduled progress, the District Engineer will notify the Contractor in writing, to improve his progress. The District Engineer should also forward a copy of this letter to the Chief Engineer and should include a note on Form 461, Weekly Construction Report for Contract work, referring to such notice. When the progress on a major item of work falls below 80 percent of scheduled progress, the District Engineer must furnish a detailed report to the Chief Engineer and recommend what action should be taken for completing the work. A separate sheet is to be included with Form 461 to show the status of delinquent Contractors.

When the Contractor fails to perform the work or furnish materials in accordance with the requirements of Form 408 and refuses to comply with the instructions, the Inspector-in-Charge must immediately inform his superior, who will, if necessary, confer with the District Engineer. If deemed advisable, the District Engineer will give the Contractor due notice, in writing, to suspend the work. The Inspector-in-Charge must carefully observe and make

a record of the conditions immediately after the work has been ordered suspended. He will then be governed by instructions from the District Engineer, who will take the necessary steps to require the Contractor to proceed with the work in accordance with the Drawings and Specifications.

Preparation of Weekly Construction Report

13. Form 476-F, Report of Work Performed, and Form 476-E, Weekly Progress Graph, are to be prepared weekly by the Inspector-in-Charge and submitted to the District Engineer as directed. Form 461, Weekly Construction Report for Contract Work, has to be in the mail not later than Friday of the same week, in order that proper distribution can be made from the Central Office on the following Monday morning.

The information to be used for determining progress and showing percentages on the Weekly Construction Report for Contract Work is obtained by proceeding in the following manner:

(a) Prepare Form 476 and/or Form 476-C, Distribution of Working Time and Minimum Equipment Requirements.
(b) Prepare Form 476-F, Report of Work Performed.
(c) Prepare Form 476-E, Weekly Progress Graph.

On Form 476 or 476-C the distribution of time should be shown in working days. The values to be entered will be determined from the analysis by the District Office on Forms 476-A, 476-B, and/or 476-D, Straight-Line Diagrams and Analysis Operations.

The purpose of Form 476-F is to show, grouped under the numbered controlling operations on Form 476, all items and quantities and the money value of work scheduled to be performed on these operations during the week.

Form 476-E, as it is developed, will indicate graphically in percentages both the actual progress of the work and the scheduled progress.

Items Included in Major Operations

14. Under the heading Grading and Drainage should normally be included the following items: Clearing and Grubbing; Class 1 and 2 Excavation (with the exception of the quantities included in bridge construction); Borrow; Class B Concrete and Cement Rubble Masonry (for end walls and retaining walls when placed during grading operations); Slope Walls (when placed during grading operations); Tree Walls; Manholes; Inlets; Drainage Pipes; Pipe Underdrains; and Cribbing.

Under the heading Laying Base should normally be included the items Subgrade, Base Courses (all types), and Subgrade Drainage.

Under the heading Bridge Construction should normally be included: Class 1, 2, and 3 Excavation (bridge construction); Bridge Wearing Surface; Class A and B Concrete (bridge construction); Plain Steel Bars (bridge construction);

Plain and Fabricated Structural Steel; Stone Backfill for Structures; Removal of Old Bridge Superstructure; Membrane Waterproofing; Temporary Bridge and Approaches; Ashlar and Cement Rubble Masonry (bridge construction); and Pressure Mortar Pointing and Surfacing.

Under the heading Laying Surface Course should normally be included: Bituminous Surface Courses (all types); Plain or Reinforced Cement Concrete Pavement; and Brick and Block Pavement. If the surface course is of a rigid type, Subgrade and Subgrade Drainage should also be included.

Special operations will include those items of work closely related to the indicated type of construction and performed at the same time.

Clean-up should normally include those items in the Contract which are not covered by any controlling operation. Such items are: Standard and Stabilized Shoulders; Class B Concrete and Cement Rubble Masonry for endwalls (when not included in Grading and Drainage); Miscellaneous Base Courses and Surface Courses; Slope Walls; Gutters; Curbing; Sidewalks; Roadside Development; Right-of-Way Fencing; Lighting; Signs; Traffic-Control Devices (when included in Contract); and Guard Fence.

The foregoing items of work for each of the major operations are listed in the order in which they should normally be performed. The District Office, however, will group the items of work to be performed for the various operations scheduled on Form 476 in the way that will be most suitable for the project under consideration.

Preparation of Form 476-F

15. After the Contract has been awarded, a master copy of Form 476-F, Report of Work Performed, will be prepared by the District Office. The Contract information is entered in columns (a), (b), (c), (d), (e), and (f), in accordance with the proper grouping of items for the controlling operations. Each grouping will show a sub-total of Contract money value for the operation in column (f). Enough copies of the master form will be prepared to provide the Inspector-in-Charge with an original and a duplicate for each week of the anticipated duration of the project.

The Inspector-in-Charge must enter in columns (g) and (h) on Form 476-F the total number of units and the money value, sub-totaled by operations, of all work performed to and including the date entered in the space for "Period Ending" at the top of the form. He will fill in two copies of the form, forwarding the original to the District Office and keeping the duplicate. This form may also be used for reporting the Contractor's monthly estimate or semi-monthly estimate of work completed.

Preparation of Form 476-E

16. The master copy of Form 476-E, Weekly Progress Chart, shall be set up on paper that will permit the making of blueprints and/or vandykes and white prints. The District Office will prepare enough copies of this master form to provide the Inspector-in-Charge with an original and a duplicate for each week of the anticipated duration of the project.

The heading of the form provides spaces for the identification of the project by Program, County, Route, Section, Application, and City, Township, or Borough. The space provided for the date will be left blank by the District Office, and the date will be filled in by the Inspector-in-Charge for each period. The bottom of the form provides spaces for recording information relating to working time, money value of work, and progress percentages.

The master copy of Form 476-E is prepared in the District Office immediately after the master copy of Form 476-F has been completed. A separate graph will be plotted for each of the major scheduled operations appearing on Form 476, and another graph representing a combination of all the scheduled operations in proper sequence must also be developed.

The graph on Form 476-E must show the scheduled numbers of days horizontally, with the numbers increasing from left to right. The number of days per unit of chart will be governed by the number of days in which the project is scheduled to be completed, but an allowance should be made for a possible overrun of time.

The graph must show the dollar values of the Contract work in the left-hand margin, with the values increasing from bottom to top. The money value per unit of chart will be governed by the total value of the Contract, but space should be allowed for an increase in the cost of the project.

The total height of the graph corresponding to the money value of the original Contract shown in the left-hand margin of the form, when transferred directly across to the right-hand side, represents 100 percent of the Contract amount. The height at the right-hand margin is to be divided into increments of 10 percent, and the 10-percent increments must be further divided into ten equal parts of 1 percent each.

The above method for setting up the dollar and percent values may be reversed at the option of the District Office; that is, the Office may fix the height representing 100 percent, rather than the height representing the Contract money value.

When the horizontal scale for the number of working days per unit and the vertical scale for the money value per unit have been established for the project, the graph for each operation can be easily constructed. To plot the graph for any operation, the first step is to find from Form 476 the scheduled dates for starting and completing the operation. On the horizontal line corresponding to zero dollars, plot the point at the number of days corresponding to the scheduled starting date. The next step is to find from Form 476-F the sub-total dollar value of the operation under consideration. Then plot a point that lies on the horizontal line corresponding to this dollar value and also on the vertical line for the number of days corresponding to the scheduled completion date for the operation. These lines establish the limits of the graph for the operation being considered. Also, a straight line joining the plotted points at the scheduled starting and completion dates is assumed to represent the scheduled progress for the operation.

By means of the inclined straight line just mentioned, it is easy to determine the schedule dollar value of the operation on any intermediate date. First, draw on the graph a vertical line at the scheduled number of working days corresponding to the selected date until it intersects the inclined straight line. From the point on the inclined line thus located, draw a horizontal line to intersect the vertical line at the left-hand margin. The desired money value corresponds to the position of the point on that margin line. Drawing the final horizontal line to intersect the vertical line at the right-hand margin will show the scheduled money value of the operation expressed as a percentage.

To compute the dollar value corresponding to each scheduled working day, find from Form 476-F the total dollar value for the entire operation, and then divide this total value by the scheduled number of working days for the operation. It should be noted that the scheduled time for completing a concrete structure includes the curing time, but this extra time is not to be considered in determining the dollar value for a scheduled working day.

On a copy of Form 476-E, the Inspector-in-Charge will plot points showing the actual status of each major operation at the end of the period just finished. To plot the point for any operation, he must locate the intersection of a vertical line for the charged number of working days and a horizontal line representing the dollar value of the work actually completed. If the point representing actual progress lies above the inclined straight line representing the scheduled progress, the Contractor is ahead of schedule; if the point is below the inclined line, the Contractor is behind schedule.

Submitting Forms

17. On the designated period-ending date, the Inspector-in-Charge must submit copies of Forms 476-F and 476-E to the District Office. On Form 476-F he should insert the proper values in columns (g) and (h) and the grand total. On Form 476-E he should plot the graphs showing the actual progress. Of course, all the necessary dates and general information should also be entered in the proper places.

The method of transporting these forms between the District Office and the Inspector-in-Charge will be determined by the District Engineer. However, if the project is so located that communications between the project site and the District Office are satisfactory, it is suggested that the following procedure be adopted: After the Report of Work Performed has been completed for the period, the progress should be plotted on the Weekly Progress Graph; one copy of each will be retained by the Inspector-in-Charge, and a copy of each forwarded to the District Office. The District Office will check these forms and then bring the actual progress up to date on the master graph. The percentages and progress then are available for use on Form 461, Weekly Construction Report for Contract Work.

Current Estimates

18. Once a month, or from time to time as the work progresses, the Assistant District Construction Engineer will estimate the approximate value of the work performed. When 90 percent of this estimated value exceeds $1000.00, the estimate should be turned in so that the Contractor will be paid, unless payment is withheld for the reason covered by Form 408. The Contractor will be paid semi-monthly if he meets all material and labor bills promptly, provides sufficient materials to carry on work, and maintains progress in accordance with the Engineer's schedule.

The purpose of making current estimates is to pay the Contractor for the work performed in a reasonable time, and to avoid holding back too large sums of money until the completion of the Contract. However, care must be used not to overpay the Contractor; and a certain amount of money should be withheld on indeterminate items. In preparing current estimates, the following conditions should be considered:

An estimate for Clearing and Grubbing should take into consideration the length of the project and the location where the most work under the item is to be performed.

The volume of Class 1 Excavation should be estimated as closely as possible, unless the actual yardage has been determined by cross-sectional measurements.

The volume of Borrow Excavation should be estimated as closely as possible, but an estimated amount of money should be withheld by the District Engineer to allow for any material that is wasted, as when an embankment is widened beyond the theoretical shoulder line or slope line.

The estimated value for Subgrade should include only the Subgrade under a completed, acceptable base or pavement. (The volume for this item should equal the total for the combaination of the base courses and full-depth paving shown in the same estimate.)

Sub-Base will be paid for at the Contract unit price per square yard complete in place as specified. The pay area will be based on the widths indicated on the cross sections and/or the widths required to obtain satisfactory drainage. No compensation will be made for the 24-inch width of Sub-Base required for the support of forms at locations where the Sub-Base does not extend to an outlet through the shoulder area. A maximum of 40 percent of completed Sub-Base may be paid for in advance of paving operations on a current estimate, provided that is has been completed in accordance with the requirements of Form 408.

As a rule, Shoulders are not paid for until after semi-final or final inspection, unless they are completed on one side of the roadway which has been opened for traffic. Estimates for payment will be based on half the length of Shoulders completed.

Stabilized Shoulders will normally be paid for when finally completed and accepted. Where part-width construction is specified, the Stabilized Shoulder on one side must be completed and paid for at the Contract unit price for a length equivalent to half the linear footage of Stabilized Shoulders completed. A maximum of 40 percent of completed Stabilized Shoulders may be paid for on a current estimate, provided that they are completed in accordance with the requirements of Form 408 and are satisfactorily maintained until final inspection.

Acceptable Base Courses may be paid for as completed and before the surface course is applied. Included in the same estimate should be a corresponding quantity of Subgrade, if such Subgrade is provided for in the Contract.

Plain Steel Bars shall be included in the estimate only after these bars have been incorporated in the work.

The policy of the Department in regard to Structural Steel is to pay for 95 percent of the total estimated weight of fabricated structural steel that has been erected and riveted, welded, or otherwise placed in final position but has not necessarily been painted. For plain structural steel required in the construction of I-beam bridges, a current estimate may include 95 percent of the total estimated weight of the steel that is in place in the structure and completely welded but has not been painted. The total estimated or actual payable weight will be included in a current estimate after the painting has been completed satisfactorily.

The Proposal may specify that Temporary Bridges and Approaches are to be constructed, maintained, and removed at a Lump Sum price for all three operations or at a Lump Sum price for each operation, in accordance with Form 408. In either case, the full amount should not be paid on a current estimate until all work under this item is completed.

Payment for Inlets, Manholes, and F-Type End Walls should be reserved until these structures are completed.

Payment for Pipe can be made only on specified lengths complete in place and backfilled satisfactorily.

For the purpose of estimating payment for other items in the Contract, the Inspector-in-Charge will have checked measurements and computations in the estimate book; and the needed values can be taken directly from that book. The Assistant District Construction Engineer must be familiar with the work as it progresses, and must have personal knowledge that the work has been performed. He, as well as any other representative of the Department who may be responsible for designated items in the Contract, should be certain that the measurements were taken and the computations made by competent Inspectors. The quantities should not exceed the preliminary estimated amounts, unless there have been approved changes in the Drawings and quantities.

Semi-Final Estimate

19. After 95 percent of the work under the Contract has been completed, the Contractor may submit a written request that an approximate semi-final

estimate be made. The amount of work completed is determined by an Engineer who estimates by inspection the percentage of the work remaining to be done. When the payment to the Contractor is based on a semi-final estimate, the amount of money retained must be at least twice the Contract value or estimated cost of the work still to be done. In case a greater amount would be needed to cover all legal and equitable deductions which may be assessable under the Contract, this greater amount must be retained.

Sometimes the quantities and money values for the items of the work remaining to be done can be deducted from the Contract quantities and values in the body of the estimate. The total amount of money under the heading "Amount Retained" will then consist of the Contract value of the work still to be done and an equal amount withheld from the value of the completed work. If the nature of the work remaining to be done is such that deduction of quantities in the itemized portion of the estimate is not practicable, the amount of money under the heading "Amount Retained" will be twice the estimated cost of the work still to be done. In either case, the character and value of the work remaining to be done shall be shown in a letter accompanying the semi-final estimate.

Final Inspection

20. When the Contractor claims that the project is completed, the Assistant District Construction Engineer and the Inspector-in-Charge must check the project to assure themselves that all work has been performed and that all receipted bills, weigh bills, releases, and other necessary documents have been obtained.

After the satisfactory completion of all work to be performed under the Contract, including any Additional, Extra, and/or Force-Account Work which has been approved, the Assistant District Construction Engineer will notify the District Construction Engineer that the Contract has been completed in accordance with the Specifications, Drawings, and Special Requirements, and that the project is ready for final inspection.

The District Engineer, or the Assistant District Engineer, or the District Construction Engineer will make a final inspection by walking over the project with the Contractor or his representative, the Inspector-in-Charge, maintenance superintendent, and any other assigned representatives of the Department, as well as representatives of public-utility companies and local political subdivisions affected. In case a portion of the work has been performed under a Public Utility Order, arrangements should be made to have the Public Utility Commission represented on the final inspection.

If the Contract is a Federal-Aid Project, the Office of the Bureau of Public Roads in Harrisburg should be notified at least 10 days in advance of the date on which this final inspection is to be made, in order that a Federal representative may arrange to be present.

If, in the opinion of the District Engineer or the person assigned by him to make the final inspection, too much work remains to be performed, this so called final inspection will be considered a semi-final inspection. In this

case, another final inspection will be made when the work has been completed; but representatives of the public-utility companies, political subdivisions, and/or the Public Utility Commission need not be present on this second inspection unless they so desire.

After the final inspection, all work remaining to be done must be completed and the Assistant District Construction Engineer must notify the District Engineer, in writing, that all physical work in connection with the project was completed on a certain date. The final payroll data should include no labor beyond that date. Upon acceptance, the completed work shall be turned over to the proper agencies for maintenance.

All records of the project must be taken or sent to the District Office. If the Inspector-in-Charge feels that the District drafting-room personnel may have difficulty in determining or computing any features or measurements, he should explain them to the Plans Engineer or to the Senior Draftsman in charge of final computations.

Final Estimate

21. In order to develop a standard statewide policy for avoiding delays in making final payments to Contractors, the following procedures have been recommended:

When a construction project involves a sizable Contract price, someone from the Department will be assigned to the field office. He will work under the direct supervision of the Engineer in charge of the project, and his main duties will be to keep records and assemble all data needed for determining the final quantities for all items of the Contract except items that are noted.

In each field office there must be a complete set of the Contract Drawings, as well as all standards and shop drawings. The man assigned to the field office will revise the Contract Drawings so that they agree with the actual construction. A set of white prints should preferably be made for showing the actual construction, but a set of blueprints may be used. The entries on these prints will be made with colored pencils; and the information recorded on them must be accurate, because they will become an official part of the final records. Only a reasonable amount of time should be spent on lettering and drafting operations.

The information recorded on the Drawings kept in the field office should in no way replace notes in the Inspector's diary. In fact, the Inspector's notes will have to be more complete in order that they will describe all the construction details shown on the Drawings.

The Inspectors must show the positions of as many points as possible on the construction-survey centerline. The P.C.'s, P.T.'s, P.O.T.'s, P.O.C.'s, and the P.I.'s that fall on the pavement are of particular importance. Horizontal measurements must be made to locate these points, and these

measurements must be made before any grade stakes are disturbed by the Contractor's operations. As stated in Form 408, the Contractor will be held responsible for the preservation of all stakes, marks, and points needed for control and guidance in his construction operations.

After the pavement has been placed, the positions of the 100-foot stations and important intermediate points, or pluses, must be accurately marked on the pavement. An encircled dot should be used for each full station, and a plus sign for each intermediate point.

Additional and Extra Work

22. While work on a project is in progress, unforeseen conditions may require changes in the Contract quantities, or it may be found necessary to do work that was not included on the Drawings or in the Proposal. Such work is covered by a Work Order.

When work that is not included in the Contract must be done, the Inspector on the project must immediately notify the Assistant District Construction Engineer or the District Engineer, in order that the necessary steps may be taken to avoid delay in the progress of the project.

Requests for approval of work not included in the Contract shall be submitted promptly to the Chief Engineer, on Form 442-A, before such work is actually started. In an emergency, however, when the work is of sufficient importance to justify immediate attention, a telephone request for permission to start on the work before written approval is received may be made to the Chief Construction Engineer or his assistant. Such a request must be confirmed promptly in writing and the written request must be accompanied by a Form 442-A covering the work.

When additional quantities are required on Contract items, the District Engineer will submit a Form 442-A covering such additional quantities to the Chief Construction Engineer for approval. When the changes in quantities are small, the unit prices shown on the Contract will apply. These unit prices also apply if the character of the work has not been changed materially. When the Contractor is willing to perform this Additional Work at the Contract unit prices, he must so indicate in writing. Copies of this letter of agreement shall be submitted with Form 442-A.

If it is necessary to do Additional Work for which the Contractor will not accept the Contract unit price, because of a change in the character of the work or for some other reason, the work also will be handled by Form 442-A. The price for such work must be one that has been agreed to by the Contractor and the Chief Engineer. Only the additional expense, without an allowance for additional profit, may be added to the Contract price. Wherever possible, a unit price should be determined for Additional Work; but a fair Lump Sum price will be acceptable.

When the District Engineer submits a Form 442-A for Additional Work to be done at other than the Contract unit price, he will make a careful estimate of the probable cost of the work, in order to obtain a satisfactory unit price or Lump Sum price from the Contractor. The Form 442-A should be accompanied by the Contractor's original letter agreeing to the adjusted price and by the District Engineer's estimate in detail justifying the price and his recommendation. No agreed-on price will be approved by the Chief Engineer unless it is clearly justified and recommended by the District Engineer.

Work for which no quantity and price are included in the Contract, and work provided for in Form 408, will be done as Extra Work. The price must be agreed upon in writing by the Contractor and the District Engineer, and approved by the Chief Engineer, before the work is started. The agreed-on price, either unit or Lump Sum, must be satisfactorily justified by the District Engineer's computations for labor, materials, and equipment required, and/or such other data as may be necessary.

When an item of work to be performed is not included in the tabulation of quantities for the project involved, but is included in the Contract on an allied project, such work should be shown as Extra Work on Form 442-A at the unit price for the allied Contract, and no item number need be indicated. Reference to the Contract price is the justification of the agreed-on price for such Extra Work.

When the District Engineer submits a Form 442-A for Extra Work at an agreed-on unit price or Lump Sum price, the price or sum must be commensurate with average Contract prices for similar items of work, and must be fully justified by proper computations of labor, materials, and equipment shown on the reverse side of the form or on a sheet attached to it.

Force-Account Work

23. When the Contractor and the District Engineer cannot agree in advance on a price for Additional Work or Extra Work, the work may be done by Force Account. In this case, the District Engineer submits a Form 442-A to the Chief Engineer for approval of the work and the method of payment, and forwards with the form a careful estimate of the probable cost of such Force-Account Work. This estimated cost, as approved by the Chief Engineer, cannot be exceeded without authorization. If it is discovered during the progress of the Force-Account Work that the amount of money authorized is going to be insufficient, a supplemental estimate and a revised Form 442-A must be submitted to the Chief Engineer, and his approval of the change must be obtained before the amount of the original Work Order is exceeded. In an emergency, where immediate action must be taken, the District Engineer will call the Chief Engineer on the telephone and request permission to do the work before the new Form 442-A is approved. If permission is granted, the telephone request must be confirmed promptly, in writing, and the written request must be submitted with the necessary Form 442-A.

When a Form 442-A is submitted for work to be done on a Force-Account basis, it is to be accompanied by computation data that are carefully itemized to justify the recommended unit prices or Lump Sum prices, in accordance with the requirements of Form 408 and Supplements to it. The additional percentages applied to the estimated costs for Force-Account Work are 15 percent for labor and 10 percent for materials; there is no additional percentage for equipment. After Force-Account Work has been completed, the actual costs are submitted to the Chief Engineer on a new Form 442-A. Also, the amount of money previously estimated is shown in the deduction column of the new form. This new form must be accompanied by certified documents from the Contractor, each of which is fully itemized and properly dated. These documents must include the labor payroll data, the record of equipment with rental rates, receipted bills for materials, and all other pertinent information.

In order that the rental rates for equipment may be readily verified, each piece of equipment must be listed with all necessary information, such as the name of the manufacturer, the type, the size (capacity in tons or cubic yards, horsepower, or cubic feet), and the source of power (gasoline, diesel, or steam).

The Inspector-in-Charge has to keep in close touch with the work done on a Force-Account basis. He must check daily, in person, the labor employed and the equipment and materials used; and he must see that the work is done in an economical and practical manner. He should compare notes daily with the Contractor's timekeeper to avoid discrepancies in the invoices submitted by the Contractor in relation to this work. He must notify the Contractor that such invoices must be rendered promptly at the end of the month in which the work is done, and that they are to be fully itemized to show dates, hours, and rates of pay. These invoices must be signed by the Contractor or his representative and the Inspector-in-Charge, and must be accompanied by receipted bills for any required materials.

Additions to Estimated Costs

24. When costs are estimated to justify recommended prices for Force-Account Work, the additional percentages must be applied properly. The 15 percent specified for labor must be applied to the wages for all laborers (including equipment operators) and foremen in direct charge of the specific operations involved in the Force-Account Work. This percentage is intended to compensate for the following items: general supervision; the use of small tools and equipment for which no rental is allowed; camp, job, and general overhead; bonding premiums; incidental expenses; and profit.

Additional percentages of the wages for laborers and foremen in direct charge of specific operations will be allowed to provide for Social Security and Unemployment Taxes, Workmen's Compensation Insurance, Contractor's Public Liability Insurance, and Contractor's Property Damage Liability Insurance. The percentage for each tax or insurance item will be the base rate in effect on the particular project.

Rates for Workmen's Compensation Insurance depend on the class of work included in the Contract, and are established from time to time by the Pennsylvania Compensation Rating and Inspection Bureau. The applicable rate must be checked from the Contractor's records of premiums paid, and certified to by the District Engineer when he transmits the forms. Since rates may be changed by the Bureau during the life of the Contract, it is necessary to check the actual percentage paid during the period to which the Work Order applies.

Rates for Contractor's Public Liability Insurance depend on the class of work included in the Contract, and are established by the Insurance Underwriters Association. The applicable rate must be checked from the Contractor's records of premiums paid, and shown accordingly.

Rates for Contractor's Property Damage Liability Insurance depend on the class of work included in the Contract, and are established by the Insurance Underwriters Association. The applicable rate must be checked from the Contractor's records of premiums paid, and shown accordingly. It may include coverage for damage due to blasting and explosions, when additional coverage is secured on projects where blasting is required.

The additional allowance of 10 percent on materials applies also to freight charges shown by original receipted bills. This allowance compensates for overhead, incidental expense, profit, and similar items.

No percentage will be allowed for overhead, incidental expense, and profit on machinery, trucks, or equipment, because the cost of using equipment will be based on fair rental rates, including fuel and lubricants, to be agreed upon in writing before the work is started.

When the Contractor is required to carry Railroads' Protective Public Liability Insurance and Railroads' Protective Property Damage Liability Insurance by Special Requirements of the Proposal and Contract, he will be allowed an additional percentage of the total direct costs of the Force-Account Work to cover such insurance. However, there must be no duplication or overlapping of charges included in the percentages for labor and materials. The applicable rates must be checked from the Contractor's records of premiums paid, and shown accordingly.

No allowance will be made for Contractor's Protective Public Liability and Property Damage Liability Insurance in the case of sub-contracting, even if provision for such protection is made in the Special Requirements, because this is a protection for the Contractor, and not for the Department.

<u>Approved Work for Property Owner</u>

25. When the District Engineer deems it advisable to have the Contractor perform certain work for a property owner adjacent to the construction, in order to lessen the property damage, or instead of a cash settlement, he must submit to the Chief Right-of-Way Engineer a complete property-damage report along with his recommendations.

Upon approval by the Chief Right-of-Way Engineer, the District Construction Engineer should then submit a Form 442-A for this extra work, noting that it has been approved and is chargeable to Property Damage Funds, as well as indicating on the face of the form the claim number of the property on which the work has been done. No work can be performed instead of a cash settlement until approval for such work has been granted by the Chief Right-of-Way Engineer.

Payment for work done for a property owner will be included in current estimates or in the final estimate.

Form 442-A for Additional, Extra, or Force-Account Work

26. Careful attention must be given to the preparation of Form 442-A, and it must be thoroughly checked before being forwarded for approval. A highway Contract may involve more than one source of financing. It may be covered by two or more Federal projects; or it may involve a combination of two or more of the following: Federal, State, State Highway and Bridge Authority, Municipal, Railroad, or other financing agency. Where there is more than one source of financing, the items of work and amounts applying to each separate project should be tabulated and summarized on a separate copy of Form 442-A.

Where the items in the Proposal and Contract indicate that alternate types of construction may be used, Form 442-A should only reflect the type which is actually being used. For example, if the Contract indicates Item 92a as Type 1-B or 2-B Guard Fence, and type 1-B is used, the form should indicate Item 92a as Type 1-B Guard Fence. In the event that different types for the same item are used on the project, the amount of each type should be shown under the given item on the form; in other words, the item number should be repeated for each alternate type used.

The correct serial number must be inserted in the upper right-hand corner of Form 442-A. If more than one project agreement is included in the Contract, or if two or more correlated Contracts are included in one highway project, the serial designation will consist of a number and a letter, such as 1-a, 2-a, 1-b, or 2-b.

The total amounts shown in the lower right-hand corner of Form 442-A for the Contract amount and the agreement amount should be only the amounts applicable to the individual project agreement concerned, and not the entire amounts applicable to combined projects or to Contracts involving two or more parts. The necessary information is obtained from the detailed Federal, or other, project-agreement tabulations of quantities, which are furnished to the District Offices by the Chief Engineer.

When certain items of work on an agreement project have been financed as "100% State", because Federal or other authorities did not approve the items for their participation,the amounts shown for the net additions and deductions must include both the amounts for items approved for Federal or other participation and the amounts for 100% State items.

When two or more sources of financing are involved, Form 442-A is used for two purposes. One use is for submitting items to the Bureau of Public Roads or other participating agency for approval or rejection. The other use is for submitting to both the Auditor General and the State Treasurer the information needed to check the current and semi-final estimates and the final certificate. Regardless of the method of financing, the totals of all additions and deductions must be shown for each separate project or separate Contract.

Work Caused by Revisions

27. Minor differences between the quantities estimated from preliminary plans and the quantities actually required for construction are often shown as errors. Such differences are unavoidable, and should not be considered as errors. Changes in quantities of this nature need not be reported or explained on a Form 442-A during the progress of the work, but may be covered by a Form 442-A submitted with the final estimate. There would be a true error if the Drawings prepared for construction showed an incorrect elevation, dimension, or detail which would cause an undesirable condition unless corrected. The District Construction Engineer should furnish a clear and complete explanation in connection with such an error.

The work indicated on a Form 442-A may involve a change in the original design of a structure or foundation, or a revision of drawings, such as a change of alignment or a change in grade. The District Engineer will then forward a sketch or print showing the changes or revisions to the Chief Engineer for approval. The revisions must be plainly marked on the print in colored pencil. The quantities required by the revision must be tabulated on the sketch or print. Revisions will be placed on the official tracings by the Chief Plans Engineer, and they will be approved with official signatures. After the revision has been placed on the official tracings, the necessary blueprints will be made. If supplemental Drawings are necessary to show the revisions clearly and are made in the District Office, the tracings must be submitted to the Chief Plans Engineer for official approval. Then the necessary blueprints will be made.

The Federal authorities require that both additions and deductions be indicated for the project. Therefore, when a Form 442-A is submitted during construction and another form is submitted for balancing the final estimate, all additions and deductions should be clearly explained and the price for each item should be justified. Sometimes, the explanation given for an item of an addition or deduction on a Form 442-A accompanying Form 2115, Final Estimate, will not be the same as the explanation applying to that item shown on a Form 442-A submitted for approval of work on a Federal project or other project. When more than one project or more than one Contract is involved, a separate explanation should accompany each Form 442-A. Also, a letter explaining the net additions and deductions on Form 2115 should be submitted with that form.

When a Form 442-A is submitted to cover a deficiency in the depth of a pavement or some other item involving a reduction in cost, the full amount of money for the original item must be deducted and the cost of the revised item shown as Extra Work at the adjusted price. Where the depth of pavement

is deficient, the required copies of Form 442-A retained for the Department records must be accompanied by a small sketch showing the location of the work, the thickness of the pavement as determined by cores or test pits, and the computed area.

Approval by Federal and State Agencies

28. The Bureau of Public Roads and the State Highway and Bridge Authority are very strict in requiring approval of Additional, Extra, or Force-Account Work entailing a change of design or an increase in any Contract item of work prior to the start of such work. These financing agencies have refused to approve orders for Extra and Force-Account Work because that work had been performed prior to submission of the request for its approval, even though the work had been minor in character. It has been necessary to finance these work orders at 100% State cost; and added clerical work is involved in separating these items on the estimates and other financial records. A special effort should be made to foresee such work and to request approval before its start, if possible, to avoid delay to the Contractor's operations. A statement that the work has or has not been performed must be included in the letter accompanying the current Form 442-A, but such a statement should not be written on the form.

If reference to an individual employed by the Bureau of Public Roads or the State Highway and Bridge Authority must be made on the back of a Form 442-A, the name of the individual should not be used. He should be identified only as a representative of the agency.

When a request is made to the Federal or State Highway and Bridge Authority for approval of Additional, Extra, or Force-Account Work, and funds in excess of the amount of money provided for in the original project agreement will be or may be needed, that fact must be stated in the request for approval. It is desirable to reduce requests for additional funds to an absolute minimum. Whenever a Form 442-A is submitted and it is possible to indicate savings equal to or greater than the increased cost of the work described in that form, an explanation of such savings should accompany the form.

If Additional, Extra, or Force-Account Work on a project involving the Federal or State Highway and Bridge Authority is not correlated, a separate current Form 442-A should be submitted for such work. This procedure will speed up approval.

Federal Projects

29. On Contract projects financed wholly or partially from Federal funds, the following instructions shall apply:

The Federal project number must always be shown. Typical numbers are FA 206 (1), FAS 540 (2), and FAGH 724 (3).

If two or more Federal projects are included in one State Contract, a separate set of Work Orders on Form 442-A must be compiled for each Federal project, and the number of the proper Federal project must be shown on each Order form.

Also, the Orders of each set shall be numbered successively. Thus, those of one set would be marked 1-a, 2-a, 3-a, and so on; and those of another set would be designated 1-b, 2-b, 3-b, and so on.

If a portion of the Contract is financed 100 percent from State funds (Federal non-participating), the number of the Federal project shall be inserted on Form 442-A, and the following note shall be placed on the face of the form: "Federal Non-Participating, 100% State Portion". A separate set of Work Orders on Form 442-A must be used for this portion of the Contract, and these Orders are to be marked serially by a number and a letter.

If the 100% State portion, or part of that portion, covers work to be performed instead of a cash settlement for property damage, a separate set of Work Orders on Form 442-A shall be compiled. On these Orders, the items of work and the total cost must be shown separately for each claim number; and above the items for each claim there must be placed on the face of the Order the following insertion: "100% State Portion--Class ( )--Claim No. ( )." Each Order must show the number of the Federal project, and it is to be marked serially by a number and a letter.

State Projects

30. On Contract projects financed wholly from State funds, the following instructions apply:

> The designation "100% State" must always be shown.

If a portion of the project covers work to be done instead of a cash settlement for property damage, the procedure is to be essentially as described in next to the last paragraph of Section 34.

State and Local Projects

31. When a Contract project is financed and executed by the State and an allied Contract is financed and executed by local authorities, the following instructions apply:

> The designation of the project must always be shown. Examples are "State & Borough" and "State & City".

Separate sets of Work Orders on Form 442-A must be used for the State portion and the local portion. On the face of each Order there is to be inserted the note "State Portion" or "Borough Portion," or some other suitable note. Also, each Order must be marked serially by a number and a letter.

Forms applying to the local portion must be approved by the local authorities.

Local Projects

32. On a Contract project financed by a single local authority or by two or more local authorities, the Department acts only as the advertising and con-

tracting agent to comply with some law, order, regulation, or agreement.

Where the project is financed by a single local authority, the designation shall be shown. Examples are "100% Borough", "100% City", and "100% County".

Where the project is financed by two or more local authorities and a single Contract is executed by all parties concerned, the designation shall be shown. Examples are "County & Borough", "Borough & City", and "County, Borough, & City".

If the cost of the work is allocated on a percentage basis, a separate set of Work Orders on Form 442-A for each participating local authority will not be necessary. If the project is divided into separate Contracts each of which is executed by an individual local authority, or if the cost of the project is set up to show specific amounts to be paid by each local authority and separate estimate breakdowns are indicated, separate sets of Orders shall be compiled. On the face of each Order there must be inserted the note "Borough Portion", "City Portion", or "County Portion", or some other suitable note. Also each Order shall be marked serially with a number and a letter. All forms must be approved by the local authorities concerned.

Instructions for Compiling Form 442-A

33. The following instructions are to be used in the preparation of Form 442-A for any project:

(a) Insert the correct serial number. If more than one project agreement is included in the Contract or if two or more correlated Contracts are included in one highway project, the designation will consist of a number and a letter, such as 1-a, 1-b, 2-a, or 2-b.
(b) Cross out the class of work that is not applicable.
(c) Insert the Contract No., the District No., the Project Section No., all Federal Project Nos., and the State Highway and Bridge Authority Project Nos.
(d) Insert the county, township, borough, or city, the Contractor's name and address, and the date of submission of Form 442-A.
(e) Insert the Contract item numbers, quantities, kinds of work, unit prices, and amounts of additions and deductions.
(f) Insert the total amounts of additions and deductions for the present Form 442-A.
(g) Insert the total amounts from the previous Form 442-A for additions and deductions for the specific project concerned (including any amounts previously approved for 100% State cost on projects financed wholly or in part from Federal funds).
(h) Insert the total additions and deductions to date for the project concerned.
(i) Insert additions or deductions.
(j) Insert the amount of the Contract or the individual project to date (amount of original Contract or project agreement breakdown, plus net additions, minus net deductions).

(k) Insert the F.P.A. (Federal Project Allocation) or other agreement designation in the space after "Maximum Amount Allowable under Agreement."

(l) On the reverse side of the duplicate, triplicate, quadruplicate, quintuplicate, and sextuplicate copies, and on those copies for the Bureau of Public Roads and/or the State Highway and Bridge Authority, insert a full explanation for each item of additions and deductions. If there is not sufficient space, attach an extra sheet to each of the copies named. When a final Form 442-A is submitted, an explanation must be given for each item of additions and deductions. Separate explanations must be given for each project when more than one project is included in the same Contract.

(m) Insert or attach the justification of the price for extra work at the agreed-on unit price or Lump Sum price. Attach the Force-Account labor payroll summary and equipment rental data; receipted bills for materials, all fully itemized; and any other pertinent data.

(n) Submit seven copies of Form 442-A and one complete set of supporting data for 100% State projects, or State and Local Authority projects. All copies all signed by the District Engineer. Attach the set of supporting data to the duplicate (Chief Engineer's) copy of Form 442-A.

(o) On State and State Highway and Bridge Authority projects, or 100% State Highway and Bridge Authority projects, submit nine copies of Form 442-A and two sets of supporting data. The two additional copies of Form 442-A and the additional set of data are for the State and Bridge Authority. All copies are signed by the District Engineer. The two additional copies of Form 442-A must be clearly marked "State Highway and Bridge Authority."

(p) On State and Federal-Aid Secondary projects, submit only the usual seven copies of Form 442-A and one set of supporting data, as for 100% State projects. No copies are required for the Bureau of Public Roads on Federal-Aid Secondary projects.

(q) On projects involving State and Federal funds, except Federal-Aid Secondary projects, submit ten copies of Form 442-A and three sets of supporting data. The additional copies are for the Bureau of Public Roads. All copies are signed by the District Engineer. The three additional copies of Form 442-A are to be clearly marked "Bureau of Public Roads." In exceptional cases, when major changes are made, additional sets of data may be requested for the Bureau of Public Roads.

(r) On State Highway and Bridge Authority and Federal-Aid projects, except Federal-Aid Secondary projects, prepare twelve copies of Form 442-A and four sets of supporting data. All copies are signed by the District Engineer.

> NOTE: The above instructions are typical and in force at the date of preparation of this manual. However, they are reviewed from time to time and revised to meet new operating procedures. Instructions for changes are given by circular letter.

Temporary Suspension of Work

34. Time is the essence of any Contract. Since delays in performing the work will inconvenience the public, obstruct traffic, interfere with business, and increase the cost to the State, it is essential that the work be pressed vigorously to completion. However, the District Engineer has full authority to suspend the work wholly or in part for such period or periods as he may deem necessary for any of the following reasons: unsuitable weather or other conditions which are considered unfavorable for performing the work; failure on the part of the Contractor to carry out orders given; failure of the Contractor to fulfil any provisions of the Contract; unforeseen conditions which had not been provided for in estimating the Contract time required for the completion of the work.

If it should become necessary to stop the work for an indefinite period for any of the reasons given above, the Contractor must do the following things: store all materials so that they will not obstruct or impede the traveling public unnecessarily, nor become damaged in any way; take every precaution to prevent damage or deterioration of the work previously performed; provide suitable drainage of the roadway by opening ditches and drains; and erect temporary structures and barricades where necessary. The Contractor must not suspend the work, however, without written authority. When conditions are again satisfactory to resume work on the project, he will be notified to do so in writing.

When the work is suspended in part, the District Engineer has the authority to direct the Contractor to do work on operations which may be performed advantageously to hasten the completion of the project.

It will not be possible to perform work on all operations during the winter. However, it is often assumed in the preparation of the schedule in Form 476 that work on the project will start in the fall and that certain controlling operations will be continued during winter periods. When scheduled work is done during winter periods, a suitable amount of Contract working time will be charged.

Whenever work on an operation is suspended, it is not to be resumed until permission is given by the District Engineer.

Opening Highway to Traffic

35. Traffic must be kept off newly constructed reinforced concrete pavement for a suitable period of time. This period is at least 10 days for normal concrete, and at least 3 days for high-early-strength concrete. However, the pavement must have developed a flexural strength of at least 550 pounds per square inch, as determined by transverse tests made on beam specimens in accordance with the Department's procedure for testing.

The District Engineer has the authority to order, in writing, any completed section of roadway to be opened to traffic. Such opening shall not be considered an acceptance of this section of roadway; nor shall it be considered

as a waiver of any provision of the Specifications and the Contract. The Contractor is required to furnish, place, and maintain approved barricades, necessary warning signs, lights, torches, and/or reflectors. Any damage to the highway improvement resulting from traffic other than the Contractor's, and not because of defective materials and/or workmanship, will be repaired or replaced at the expense of the Department.

If the Contractor takes too long to complete shoulders, drainage structures, or other features of the work, the District Engineer may order all or a portion of the project opened to traffic. However, the Contractor will not be relieved of his liability and responsibility until the entire project is accepted. Prior to final acceptance, the Contractor must conduct the remainder of his construction operations so as to cause the least obstruction to traffic.

Where one-lane traffic is declared necessary, as in the case of a bituminous surfacing project, the Engineer or the Inspector must insist that the Contractor limit the length of such a lane so as to cause the least inconvenience or delay to the traveling public.

The Engineer or the Inspector must insist that all flagmen assigned to the project conduct themselves in an efficient and acceptable manner, and at all times treat the traveling public with proper courtesy.

There may be times when the District Engineer may order a section or certain sections of a project completed in accordance with Form 408. Seasonal, local, or unusual conditions encountered on the project may justify this action. Long temporary routes, which are especially undesirable during the winter months, may thus be shortened or even eliminated.

CHAPTER III

GENERAL POLICIES

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Relations With the Contractor

1. The Contractor is the individual, firm or corporation who has agreed to do the construction work in the way described in the Contract. The Contractor agrees to do this work for the price that he gives in his bid and takes a chance on losing money if it costs more than the bid price to do the work. For this reason, he has a right to a fair profit. The Engineers and Inspectors will help the Contractor to get a good job; but, they must see that he does all the work and that he does it in the way he agreed to. This means meeting all of the requirements of the Special Provision of the Proposal, the Contract Drawings, and the Specifications, and approved changes.

The Contractor is responsible for the project from the day the work starts until he gets a Final Inspection from the Department. He must keep the project under his control at all times, and must see that the work is not slowed up because of poor supervision.

The fact that there are Inspectors on the job does not reduce the Contractor's responsibility.

The Contractor must have a superintendent or representative on the project at all times who is experienced, familiar with Pennsylvania Department of Highway ways of doing things, and able to do the work exactly as described in the Proposal and Specifications, and shown on the Drawings. When the Contractor's superintendent or foremen are not able to do their job, it is the duty of the Inspector-in-Charge to report it to the Assistant Construction Engineer.

The Contractor must be told right away about any incorrect methods used or any unsatisfactory work done. If things are not promptly set to rights, the Inspector-in-Charge must report in writing to the District Construction Engineer and make detailed records in his diary of all important instructions or warnings given, and including any agreements which have been made.

Inspectors must be on the job before the work starts in the morning and stay on the job until all important operations such as placing and rolling embankment, or finishing concrete, have been completed. When the Contractor has to do work after the usual working hours, the Inspector must stay on the job or arrange with the Inspector-in-Charge to get off.

A complaint by the Contractor that the Inspector has been late, or was not on the job, hurts both the Inspector and the Department. During bad weather, or when the job is shut down, Inspectors must make sure that they leave word where they will be before they leave the job. The Contractor or visiting Engineers should be able to get in touch with any Inspector in a hurry.

It is easy for an Inspector to become known as lacking interest in his job of seeing that the work is done according to the Specifications. The Inspector who wants to keep a good reputation will always make prompt objection to any unsatisfactory work directly to the Contractor, or his superintendent or foremen. This will head off any arguments later on, when the work has to be repaired or done over.

The Inspector must work with the Contractor in getting the work done, and be tactful and firm in enforcing the requirements of the Proposal, Drawings, and Specifications. The Inspector must be open-minded, avoid jumping to conclusions, be fair and just, and, in case of doubtful situations, get in touch with his superior promptly. Any orders must be given to the Contractor, to his superintendent or to his representative, such as the foreman. The Inspector must not give orders to laborers or other workmen on the project.

The Inspector must think problems through before making decisions. He must discuss problems with the Contractor, but must avoid useless arguments. When he is sure he has reached the right decision, he must be prepared to be firm. He must never allow himself to be threatened by the Contractor. Any trouble should be reported to the Inspector-in-Charge.

In case there is a disagreement between the Inspector and the Contractor or his representative about unsuitable materials, poor workmanship, inadequate equipment, or weather unsuitable for construction operations, the Inspector has the authority to reject materials or hold up the work until a decision can be obtained from the Inspector-in-Charge or higher authority. Inspectors must use their own judgment when making decisions on small points not covered in written instructions, but important points should be brought to the attention of the Inspector-in-Charge or higher authority. Inspectors should realize that the Contractor has the right to appeal to higher authority in cases of differences of opinion.

In most cases, the Inspector's decision will be backed up, but he should be big enough to go along with the judgment of his superior if he is overruled. He should realize that for the sake of the Department his superior will treat his men fairly and will overrule them only when he thinks the best interests of the Department have not been served.

When it is expected that claims may be made by the Contractor, the Inspector-in-Charge of the project must notify the Assistant District Construction Engineer promptly, and records must be kept of all labor, material, and equipment used on this part of the work.

The Inspector should know in advance what materials and equipment the Contractor will need, and should give him any advice which will help him to do things according to Specifications without being held up.

He should never tell the Contractor <u>how</u> to perform any part of the construction, but should call attention to any poor workmanship, or any operation which will result in construction which will not meet the Specifications.

Under no conditions can the Inspector act as the Contractor's superintendent or foreman or operate or adjust any of the construction equipment.

The Inspector must not accept gifts or money from the Contractor. This means that all offers of free meals, gas for his car or any other form of gift must be politely refused. The Inspector must never borrow money from the Contractor or make business "deals" with him. Inspectors must always be very careful not to get into these types of relationships with the Contractor since improper actions can lead to the Inspector's instant discharge.

Relations with Public Utility Companies

2. As soon as the District Engineer has been informed by the Chief Engineer that a project is to be started, he will make arrangements for clearing the Right-of-Way of obstructions so that the Contractor will not be held up; and for the removal, resetting, construction or reconstruction of public utilities which may hinder the Contractor's operations. These arrangements by the District Engineer do not make the Contractor less responsible for public and private structures on the project.

When the Contract is awarded the Contractor must notify the owners of any structures or tracks on the Right-of-Way which may have to be moved or rebuilt. He must give notice of his plan of operations in time for them to get ready for the work and do it at the same time as or before his own operations.

The Department will show any known structures on the Contract Drawings, but the showing of a structure or leaving off any structure which is on, under, or over the project does not change the Contractor's responsibility. The Contractor is always responsible for locating any structures which affect the project.

The District Engineer makes agreements with railroads to do necessary work and to pay for this work. The Inspector-in-Charge of the project should study these agreements and keep a record of the work done so that a check can be made on the invoices when they are sent in.

Relations with Bureau of Public Roads

3. On projects where all or part of the cost is paid with Federal funds, the terms are set up in an agreement between the Department and the Bureau of Public Roads. The agreement says that the work must be done as required by the Drawings and Specifications, the Standard Drawings, and any Special Provisions in the Proposal that the project requires. The Contract is awarded by the Department of Highways with the approval of the Bureau of Public Roads. The Department does the engineering supervision and inspection.

After the award of the Contract, no change in methods, items, quantities or Drawings can be made. The Federal Government cannot be expected to pay part of the cost of any additions unless they have first been approved by

the Bureau of Public Roads. In cases where changes seem desirable, the approval of the Bureau of Public Roads must be obtained before any of the work is started. If this is not done the Department will have to pay the whole cost of any work which was not authorized in advance.

Engineers from the Bureau of Public Roads will make inspections of Federal-Aid projects from time to time, and they are to be helped in every way. All important features of the project are to be pointed out to them, including extra work and recommended changes. Any advice or suggestions offered by them should be noted in the field diary and promptly passed on by the Inspector-in-Charge to the Assistant Construction Engineer.

Relations with the Public

4. The highways in Pennsylvania are paid for by the public. The money comes from automobile license fees and gasoline taxes. Every time anyone buys a gallon of gasoline he is paying for some part of the highway system, and it is the job of every member of the Department of Highways, from the Chief Engineer to the Inspectors, to see that the public gets its moneys worth. The public pays the employees of the Department to plan and supervise the building of roads and bridges which make it possible to travel easily and pleasantly. They must also be built so that they do not cost a lot to maintain. As an employee of the Department, YOU have an obligation to see that a good job of construction is done and it helps you when the public knows that the Department is doing a good job.

Both the Department and the public are made up of individuals and the impression people get of the Department depends on their contacts with YOU. Just as the public judges a highway by its appearance and smoothness, people will judge the Department by how you look and act. Always remember that when talking to people on the job you represent the Pennsylvania Department of Highways. Be sure that your relations with people are businesslike but always friendly.

Always be courteous. When asked a question to which a factual answer can be given, you should answer it politely with the facts. If you do not have the information, or if the question is about action that the Department may, or may not, take, do not guess or express opinions but tell who to get in touch with to get the right answer and explain why they should do so. Never argue with people at any time. However, always listen to any advice given, since it shows that the public is interested in the work of the Department. For example, an Inspector should get all of the information possible on faulty drainage conditions from people living along a project. He should pass this on to the Inspector-in-Charge, as it may point out the need for changes in the sizes of bridges or culverts or the design of sub-surface drainage.

Provisions for Right-of-Way

5. Right-of-Way is the strip of land which the Department gets and uses for highway purposes. The State gets a Right-of-Way over private land in

a legal way called condemnation. A Right-of-Way condemnation plan is signed by the Governor, giving the State the right to use the land for public purposes.

People whose property will be affected by the construction will be notified of the condemnation either by personal contact, or by letter from the Department of Highways. Right-of-Way Agents will then call on the property owners to answer their questions and help to settle their claims.

Payment is based on the local market value of the property. If the whole property is taken, the owner will get the same price that would have been paid if he sold it or hired a real estate agent to sell it. The owner does not have to pay any commission and will get the full price of his land from the State.

Getting Rights-of-Way or permission to do highway work on private land is the job of the Right-of-Way Unit of the Department.

Everyone who works for the Department must help the Right-of-Way Unit in their work whenever possible. Any information which may show how the owner feels about having a highway built on his property or on the cost of the Right-of-Way should be given to the Inspector-in-Charge who will pass it on to the District Right-of-Way Engineer.

Construction Inspectors must not talk about Right-of-Way matters with property owners in any but general terms. When asked about such matters, the answers should be factual and without opinion, but if about what the Department may, or may not do, they should be told that the Inspector-in-Charge will get the answer from the District Right-of-Way Engineer.

The Department hires local real estate agents, who are appraisers, to help set a fair price for the property. These appraisers know the value of all property in the neighborhood, and the owners can be sure that they will be paid a fair price for their property.

<u>Provision for Public Convenience and Safety</u>

6. Usually a project is wholly or partly closed to traffic while the work is going on, and it is the job of the Department to work out a detour for the use of the public during this period. The way this is to be done will be shown on the Contract Drawings, but the Special Provisions of the Proposal and the plan of operation agreed to by the Contractor and the District Engineer must be checked to see if some special arrangement has been made. All detours must be arranged with and approved by the District Traffic Engineer. The Sections of highway closed to traffic will be closed by the Contractor as set forth in the Specifications.

When projects require detours over roads not maintained by the State, the routes will be set by written agreement between the local authorities and the District Engineer. The detours will be maintained by the local government, and routes will be posted by the Department.

The Inspector-in-Charge must plan ahead for setting up the detour and advise the Assistant Construction Engineer, who will make arrangements with the District Traffic Engineer at least two weeks in advance for the posting of traffic signs by Department forces. If the date for the detour is changed, at least two working day's notice must be given the District Traffic Engineer to set up the route. The Contractor will furnish and put up barricades and warning signs at each end of the project next to the beginning and ending of the construction, and also at the intersecting side road nearest each end to keep traffic from entering. Whenever possible, however, local traffic must be allowed to and from the nearest intersecting public highway.

It is the policy not to close a highway to traffic and set up a detour until the Contractor's operation requires it. The highway must be reopened to traffic as soon as possible. If the Contractor's operation would not be slowed much by traffic moving through the project, the through traffic should not be detoured.

The Inspector-in-Charge must see to it that the Contractor provides enough Standard signs, barricades, lights, and other protection, and that they are properly placed and maintained. Bulletin 43 should be used as a guide by the Inspector-in-Charge.

Barricades and warning signs must be protected at night with red lights, torches and approved reflectors as indicated in the Specifications. The "Penalty" signs will be furnished by the Department to the Contractor for placing. The barricades are furnished, placed and maintained by the Contractor. The "Road Closed", "Arrow", and "Penalty" signs are securely fastened to them, and they are placed where they will be plainly visible at all times.

Barricades, warning and temporary route signs, red lights, and other protection not right next to the project are furnished, placed and maintained by Department Maintenance forces supervised by the District Traffic Engineer, unless otherwise specified.

When the Proposal or Drawings require the Contractor to maintain traffic, the work must be in accordance with Bulletin 43, the Contract, and the Drawings. Traffic requirements and the Contractor's operations must be studied daily so that the work can be done with the least delay of traffic. The Contractor must not be allowed to tie up traffic for longer than necessary. THE DEPARTMENT MUST SEE THAT THE TRAVELING PUBLIC IS DELAYED AS LITTLE AS POSSIBLE BY CONSTRUCTION OPERATIONS. THERE MUST BE THE HIGHEST REGARD FOR SAFETY AND SAFE TRAFFIC CONTROL.

On projects where traffic is directed over all or a portion of the project, the roadbed maintained by the Contractor must be drained, and open and passable to traffic at all times. It must be as wide as possible without interfering with the Contractor's operations.

The Inspector-in-Charge must see that enough flagmen are furnished by the Contractor and that they have been told how to protect the completed part of the work as well as the right way to direct traffic.

An existing earth road or an improved road which has been graded by the Contractor is to be maintained as an earth road, if it is used as a detour. Surfaced roads which have not been graded are to be maintained as they were. When traffic is being maintained on a portion of an old surfaced road and a part of the shoulder, the Contractor must maintain the shoulder.

The Inspector must not ever permit the Contractor to close the road until the detour has been set up and properly marked. If, during inspection of a detour, conditions that are unsafe for the traveling public are found, the Inspector-in-Charge should immediately inform the Assistant Construction Engineer.

CHAPTER IV

CLEARING AND GRUBBING; EARTHWORK; SUBBASE; AND SHOULDER CONSTRUCTION

CONTENTS

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CLEARING AND GRUBBING; EARTHWORK; SUBBASE; AND SHOULDER CONSTRUCTION

Introduction

1. Steps in building the parts of a highway that support the pavement are: clearing and grubbing; ditching for temporary drainage; and making cuts* and fills* (earthwork). Along with the construction of the fills (embankment) the larger drainage structures are built. When the embankment* is finished and the cuts are made, the subgrade* surface is prepared and subgrade drainage* put in.

Each step is important in getting a long lasting highway with a good riding surface. The pavement must be supported by a firm foundation. This can only be had when each step in the construction is given detailed attention.

Pre-Construction Requirements

2. Before any construction begins, there are certain job details the Inspector-in-Charge must be familiar with. Some of these items are:

The Contractor's proposed method of operation.

The equipment the Contractor intends to use.

Status of getting written approval from property owners for use of their property for disposal of waste, or for use as borrow pits*, extension of slopes* beyond right-of-way; or construction of private driveways.

Steps taken for protection or relocation of monuments* and markers.

Proposed location of topsoil* stockpiles*.

Steps taken to protect valuable trees.

The Inspector-in-Charge must know, and understand, the items in the Special Provisions of the Proposal, the Contract, and the Specifications*, which apply to the job. He must make sure that all the preconstruction items have been taken care of.

The Inspector-in-Charge and the Contractor must agree on how these things are to be done, when they are to be done, and who is going to do them, before construction starts.

NOTE: Words marked with an (*) are explained in the word list at the back of this book.

Unless this is done equipment may stand idle and the work may be delayed, while decisions are being made and approvals obtained. Also, many arguments may come up during construction, or a delay may result in the Contractor making a claim*. Claims increase the amount of paper work and may increase the cost of the project.

An efficient and smooth-running job can be had if pre-construction requirements are met by prompt action.

Notice to Property Owners

3. The owner of land affected by construction should be notified by the Inspector-in-Charge or the Project Engineer, before work begins. The landowner may need to build a new fence, or to remove trees, shrubs, flowers or personal property from the right-of-way. If he is notified soon enough, he will be able to have such things done in time to not interfere with the contract work.

Preservation and Protection of Monuments and Markers

4. Monuments* such as a permanent bench mark* or other reference marker, located inside or near the right-of-way, must be protected or removed. If the monument must be removed, its owner must be given enough time to set reference marks for replacing the monuments after the construction work has been done, or to set a substitute monument in a new location.

The Contractor's attention should be called to any monuments which are near enough to the project to be in danger, so that he can make arrangements to protect them from accidental damage by his equipment.

Disposal of Waste Material

5. When equipment such as graders, bulldozers or shovels is used for clearing and grubbing, care must be taken that topsoil or suitable material needed for embankment, including wet material which can be dried, is not wasted. Waste material removed by the Clearing and Grubbing operation must be burned, or removed from the project. Care must be taken when burning brush, trees or stumps. The Contractor should be told that he must meet the requirements of laws having to do with fire control. The Contractor may want to dispose of such material by placing it on property next to the project instead of burning it. This is not to be permitted if it creates an unsightly condition along the highway. If waste material is disposed of in this manner, the Contractor must furnish the District Engineer with a letter signed by the property owner giving permission, and releasing both the local authorities and the Department from any damage claims. Material must be so spread that it will have a neat appearance when seen from the highway, will not be a source of trouble to the landowner, and will not interfere with any existing drainage. Disposal of material should be taken care of promptly so that it will not be necessary at the time of final inspection to

list stumps, brush and other trash that should have been disposed of during the Clearing and Grubbing operation.

Topsoil Stockpile Location

6. Arrangements should be made in advance as to what topsoil is to be saved and where it is to be stockpiled. An estimate must be made as to how much topsoil will actually be needed and how much can be gotten within the grading limits of the project. Usually about 20 percent more topsoil over the quantities shown on the plans, will be needed to make up for compaction and hauling losses. The depth of good topsoil is usually about 7 inches. The Assistant District Construction Engineer will decide where to make the stockpiles and give instructions as to the quantity and quality of topsoil to be saved.

Protection of Trees

7. Special care must be taken not to destroy valuable or historical trees that can be saved. It may be possible to save such a tree that is located close to the toe or top of a slope by changing the slope slightly or by building a tree wall. Such cases should be brought to the attention of the Assistant District Construction Engineer.

Sometimes the root system of a tree outside a cut may be damaged as the cut is made. The tree later may weaken and fall on the road. The Roadside Development Engineer should be asked to decide whether or not such a tree should be removed during clearing and grubbing.

Stakes for Clearing and Grubbing

8. Enough slope stakes* should be set to guide the Contractor during the Clearing and Grubbing operations. Between these stakes the line where the side slopes of cuts or fills meet the natural ground surface should be marked by temporary flagged stakes, or in some other way, to show where Clearing and Grubbing is to be done.

Slope Stakes

9. Before grading operations are started slope stakes must be set accurately at the points described in the Specifications. The Inspector should check these stakes against the Contract Drawings or Cross-sections to make sure that provisions for widened pavement, shoulders, gutters, rounding of slopes or special side ditches have not been overlooked.

In light cuts and fills, stakes should be set and string lines placed for some distance ahead to show the locations of the edges of the roadway and the amount of cut or fill required. For this purpose a number of tall stakes may be set in a row at a uniform distance from the centerline of the roadway. If possible, these stakes should be clear of the excavation limits and grading operations. Each stake should be

marked to show the distance above or below grade at that point. Where there is a light fill, the actual elevation of the grade can be shown. The deepest point in a light cut can be found and points marked on the stakes at a uniform distance above grade. If, for example, it is found that the greatest depth of cut is about 4-1/2 feet, each stake can be marked at a point an even 5 feet above grade. By stretching string lines on the stakes through these points, the Inspector can check by eye whether the line and the grade are as shown on the Contract Drawings. If anything is found to be wrong, correction can be made before grading operations are started.

In very deep cuts and fills, other ways of marking and checking line and grade can be worked out.

Preservation and Protection of Construction Stakes

10. Before starting work, the Contractor should furnish and place guard stakes 3 to 4 feet high next to all construction stakes. The Contractor is responsible for protecting all stakes from dislocation or damage. Whenever stakes or markers have been unnecessarily disturbed by the Contractor, he will have to pay for replacing them.

Scope of Clearing and Grubbing

11. Clearing and Grubbing means removing and getting rid of all material affecting the construction of a highway. The Specifications describe what is to be removed, and to what depth, under different grading conditions. When there is no Clearing and Grubbing item in the Contract, payment is included under other items.

The Contractor must keep the right-of-way well drained during clearing and grubbing. All clearing and grubbing must be finished inside the staked limits of a definite length of the project before any grading is started in that part of the work, except that stumps may be left in cuts and removed during grading.

Preventing Water Pockets

12. Any holes left by the removal of stumps or by pulling utility poles must be refilled with embankment material. This material must be compacted as required by the Specifications. If this is not done right away, these holes will fill with water and soften up the soil that will be the foundation for the subbase or embankment. Any basement floors, remaining after the removal of buildings, should be broken up so that they will not form pockets which will trap water and cause an unstable* condition in the embankment constructed over them.

Measurements and Records for Excavation

13. Unless there is much more excavation than fill in a grading section and waste of material is not important, the Inspector must make complete measurements. He must keep a permanent record of all material wasted by the Contractor beyond the limits of the standard cross sections* and in locations not covered by them. No waste of excavated material should be permitted without the approval of the Assistant District Construction Engineer.

If there is extra material from excavation in a grading section, the Contractor may be directed to use this material for widening embankments, flattening side slopes, constructing wider shoulders, or for filling holes and improving the right-of-way. However, the final cross sections must show where the extra material was placed and any contours* affected.

A daily record must be kept of the widths of cuts and fills and of the finished grade*. This record is kept in a special grading book, or on special forms. Any differences from what is shown on the Plans should be noted, along with reasons for them.

If the Contractor hauls excavated material from one grading section into another without first getting written permission from the Engineer, the two grading sections are combined and the Contractor will not be paid for overhaul. When overhaul* is to be permitted, the Inspector-in-Charge must arrange for excavation cross sections to be taken before grading begins. Accurate measurements must be recorded for computing quantities for overhaul payment.

Material obtained from one borrow pit normally should not be placed in more than one grading section. In case such material is used in more than one section, the pit should be so cross-sectioned that computations will show clearly the amount of Borrow Excavation used in each grading section. If the Contractor uses material from one borrow pit in two or more grading sections without taking cross sections and making separate computations for each section, those grading sections will be combined and treated as a single section.

The Contractor should be informed of any needed extra grading so it can be done along with the work shown or noted on the Contract Drawings.

The Inspector-in-Charge must keep a complete record of all excavation impossible to measure at the time of final survey. He must prepare a profile* and a cross section* of each private driveway or of any excavation made in the construction of a side road, or any other work, unless the survey corps has cross-sectioned the area before. He should also give special attention to sections of the Specifications which cover miscellaneous excavation and payment to the Contractor for the removal of stone fences, piles of stone, and bounders. Parallel ditches next to the roadway will be included in the final cross sections.

However, payment for all other ditches will be based on sketches, measurements, and computations made by the Inspector-in-Charge.

Control of Slopes and Limits of Excavation

14. In either a cut or a fill, the Inspector-in-Charge must check the side slopes often enough, while the grading is being done, to be sure that they are as shown on the Contract Drawings.

The slopes of a cut made with power equipment must show an even appearance. Good results can be obtained only by constant checking to make sure that the edges of cuts and fills pass through the lines set by the slope stakes, and that the surface of the subgrade is at the right elevation and has the width shown on the cross sections. As mentioned before, records of finished cross sections must be kept in a special grading book or on forms furnished for this purpose. Any difference from elevation or cross section shown on the Contract Drawings should be described by a note. Also, the Contractor's representative and the Assistant District Construction Engineer should be informed while the work is being done.

The tops of slopes are to be rounded off as shown by the Contract Drawings and wherever else rounding seems necessary. Rounding helps to reduce the amount of material falling from the slopes onto the shoulders; makes planting easier; and improves appearance. The Contractor need not round off slopes cut from solid rock, hard shale, or other hard material.

The Inspector-in-Charge must check the Contract Drawings and cross sections to see if the slopes called for at any place are flatter or steeper than those usually constructed. In an excavation, he should compare the types of materials actually found with the types shown on the Contract Drawings, soil reports, soil profile, and cross sections. If the material found in the cut is not of the type expected, and a change in the side slope seems necessary, the Assistant District Construction Engineer should be informed.

The Contractor should never be allowed to undercut* a slope in a cut and then raise the low spot back to grade by dumping in fill material. This added material is likely to slide down onto the roadway. Removing slide material after the road has been opened to traffic and repairing damage of this type is costly. Where a storm sewer* is to be placed in a trench alongside the highway, the position of the sewer shown on the Drawings should be studied carefully.

It is not usually best to excavate part of the required width first and then widen the cut later. This method slows drying of the subgrade, interferes with drainage, and does not allow a thorough study of soil or drainage conditions. Wherever possible, material should be

excavated across the full width of the cut and the side ditches dug at the same time. The center of the cut area should be kept crowned at all times so water will drain to the ditches. Each ditch should be cut through to an outlet.

If blasting is required to loosen material to be excavated, it is difficult to follow exactly the slope lines shown on the Contract Drawings. Special attention should be given to cuts where definite slopes are shown on the Drawings for solid rock, rock and earth, and loose-rock overburden*. According to the Specifications, rock is to be excavated to the slope lines shown on the Drawings, or as directed by the Engineer, from the ditch level to a level 6 feet higher. Above the 6-foot level, the rock is to be removed so that the surface is not more than 12 inches above or below the slope line shown on the plans. The Contractor will be paid for the actual volume excavated within these limits. There should be no sharp break at the 6-foot level; any change in slope at that point must be gradual. All loose material must be removed. The Inspector-in-Charge must make sure that the Contractor understands these requirements of the Specifications.

When the Contractor, with written permission, excavates beyond the slope lines shown on the Contract Drawings in order to get more material, he will be paid for the extra excavation. The rate of pay for any volume between the plan slope line, the actual slope, and a vertical line at the right-of-way limit will be either the Contract unit price for Class 1 Excavation or that for Borrow Excavation, whichever is lower. If the extra excavation extends beyond the right-of-way limit, the rate of pay for the volume outside a vertical line at the right-of-way limit will be the contract unit price for Borrow Excavation. Before excavation of material beyond the right-of-way limit is started, the Contractor must give the Inspector-in-Charge signed releases from the owners of the property affected.

<u>Use of Excavated Material for Embankment and Other Work</u>

15. The Inspector must know what kinds of work are included in each class of excavation, what volume of excavation the Contractor will be paid for, and how that volume is to be measured.

The Inspector must also know whether or not excavated material is suitable for use in embankments. If material is suitable for such use, it should never be wasted without the permission of the Assistant District Construction Engineer. Wet or frozen material may be suitable when dried out. The use of Borrow Excavation* for an embankment should not be permitted until all suitable material has been used.

To make certain that all suitable excavated material will be used for embankments and the use of Borrow Excavation kept as low as possible, the project is divided into a number of grading sections. Before any material is excavated, the Inspector-in-Charge should mark with flags the limits of each grading section on the project. Locations of

the grading sections and the Excavation summary are shown on the Contract Drawings, as are typical cross sections.

As stated in the Specifications, the Contractor may make use of any suitable stone, gravel, sand, or other natural material found in any excavation, for other than embankment use. Such material must meet the requirements of the Specifications for the class of work in which it is to be used, and its use must be approved by the District Soils Engineer. If the Contractor is allowed to use excavated material in a pavement or other structure, he will be paid for excavating the material as if it were to be used in an embankment. This material must be replaced with embankment material, for which he will not be paid. The volume of soil used for replacement must be equal to the volume of sand removed for use in the pavement or other structure. If the removed material is stone or gravel, it must be replaced by a 10 percent greater volume of good embankment material.

Hauling Excavated Material

16. Where materials from both roadway excavation and borrow excavation are to be used for fills in one grading section, the Contractor is expected to do all the grading work in this section without hauling material to or from other sections. That is one reason for dividing the project into grading sections. Normally, all roadway excavation should be completed in a section before borrow excavation is started. Grading sections cannot be combined without the written permission of the District Engineer.

In case the Engineer gives the Contractor written instructions to haul excavated material from one grading section into another, overhaul* payment may be made to the Contractor. The rate of payment per cubic yard per 100 feet of overhaul beyond the end of the grading section in which the excavated material was originally located is set by the Specifications. However, if the Contractor hauls excavated material from one grading section into another without first getting written approval, the two sections affected will be treated as one grading section in computing the payment for earthwork.

Removal of Unsuitable Material

17. Removal of decayed vegetable matter or other unsuitable material from below the surface of the original ground is not included in Clearing and Grubbing. If the Contractor is required to remove any such material in the grading operations, to provide a good foundation under a subbase or an embankment, he should be paid for the work as Class 1 Excavation. The unsuitable material must be disposed of outside the limits of the roadway.

In every case the volume of excavation for the removal of unsuitable material must be measured separately, and accurate records kept to show how much of this material is removed. Where the poor material is above

the level of the subgrade* surface in a cut, the Contractor does not get extra pay for excavating it; its removal is included as part of the regular grading operation. But the volume of wasted poor material must be measured in order that the Inspector-in-Charge will know how much of the excavated material must be replaced with suitable material to make an embankment. Where the poor material is below the surface of the subgrade in a cut or below the natural ground surface under an embankment, the Contractor will be paid for excavating it as Class 1 Excavation.

Before any excavation is begun to remove unsuitable material from below the subgrade in a cut or from below the natural ground surface under an embankment, approval should be obtained from the Assistant District Construction Engineer. If there is any doubt about the quality of the material, the District Soils Engineer should be asked for advice as to what should be done.

Disposal of Existing Highway Structures

18. The Contractor is required by the Specifications to remove and dispose of the material in any existing highway structure* on the project which will not be left in place or used in the new construction. Such material from a State highway usually becomes the property of the Contractor. Exceptions are drainage pipes, guard fence and its castings, guard posts, bridges not the property of the State, and portions of Department bridges described in the Proposal or shown on the Contract Drawings. Materials to be saved must be removed without damage, and stored where easily available to the Department. The Department Maintenance Superintendent is to be notified when this material is available.

Stream-Channel and Other Wet Excavation

19. When a small stream is to be relocated or a new channel dug, excavation of material from the existing stream channel should be put off as long as possible, to reduce the danger of damage from heavy rains. If the work will affect pools or stream sections containing fish, the Fish Commission must be notified before the excavation is started. The Commission can then make arrangements to transfer the fish. The Inspector-in-Charge should notify the Assistant District Construction Engineer, who then asks the District Engineer to send the necessary notices to the Fish Commission.

Sometimes material excavated from a stream channel, ditch or other cut, is too wet to be used in an embankment, but would be suitable if it were first dried. The Contractor must dry the wet material to the right moisture content before placing it in the embankment. He does not get any extra, or separate, payment for drying or rehandling wet material. To save time, the Contractor may waste wet material from a stream bed and use suitable material from a borrow pit. If he does so, he must dispose of the wet material and excavate and haul the new material at his own expense.

The Assistant District Construction Engineer will inspect a new drainage channel that has a bottom width of 8 feet or more. The Contractor is to inform him, in writing, when the excavation has been completed in accordance with the Contract Drawings or other requirements. If the channel is satisfactory, it will be cross-sectioned and the measurements used as the basis for current and final payments for this part of the excavation. If the District Engineer later orders, in writing, additional work to be done on the channel, the additional excavation will be measured and paid for separately.

It sometimes happens that a large amount of water flows into an excavation from the surface of the ground next to it. The Inspector-in-Charge should study the situation to see if there is any way of cutting off this flow, or draining the water away from the excavation, so the excavated material will be as dry as possible.

Ditches and Other Excavation

20. Any ditches which will run alongside an embankment should be dug before the embankment is started. Ditches alongside the roadway in cut sections should be shaped as the cut is made. In either case, these drainage ditches will give rainwater a chance to run off before it can soak into and soften the soil under the roadway. Ditches also help to dry up the construction site by lowering the ground-water level. It is always good practice to cut the ditches to their full depth as soon as possible. Each ditch must be cut all the way through to an outlet and graded so that water will not stand in the ditch.

It is the duty of the Inspector-in-Charge, to see to it that, under normal conditions, all excavation and embankment is kept inside the limits shown on the Contract Drawings and cross sections. He must make sure that additional cross sections are taken where necessary, as at slides, widened cuts, embankments with flattened slopes, and borrow pits*. Accurate measurements must be made and recorded to cover any excavation which has not been cross sectioned by the survey corps.

Excavation of Private Driveways

21. Before excavation is started on a private driveway extending beyond the right-of-way, the written approval of the owner of the driveway must be obtained by an agent of the Department. This should be done as soon as possible so the Contractor's operations won't be held up. All approvals, signed by the property owners, for driveways built during construction are to be filed with the District Right-of-Way Unit when the project is completed. Information about the work done on private driveways, or the reasons for not doing all the work, will be shown on the final construction plans. A private driveway must not be surfaced until this work is authorized in writing by the District Engineer.

Removal of Unsuitable Hard Material From Subgrade

22. The removal of loose rock, boulders, rock ledges, rigid pavement, bases, and other unsuitable hard material from below the subgrade surface, in order to get a uniform subgrade, is covered in detail in the Specifications. For removing such material, the Contractor will be paid the Contract Unit price for Class 1 Excavation. Accurate measurements must be made and recorded by the Inspector, as they will be the only data available for making up the final Estimate.

When pipe underdrains* are to be placed in rock or hard shale, blasting may be necessary. Since blasting is not allowed near a pavement, this work must be done along with the grading. Excavation for laterals* should be taken care of at the same time.

Pavement or base must not be broken by the weight-dropping method where this operation may damage any buildings, utility structures, or other construction.

Unauthorized Excavation

23. In some places it is necessary to remove unsuitable material from below the design grade line, or to excavate good material from outside the design cross section in a cut to obtain additional material for an embankment. When such extra excavation is authorized by the District Engineer in writing, the Contractor will be paid for the work in accordance with the Specifications. However, the Contractor must be warned that unauthorized excavation below the grade line shown on the Contract Drawings will not be paid for. He will be required to fill these low spots at his own expense with approved material compacted in accordance with the Specifications.

Borrow Excavation

24. It is the Contractor's responsibility to locate borrow pits from which material meeting the Specifications can be taken, and these pits must be approved by the District Engineer. Material can be excavated from an approved pit only after the site has been cleared and grubbed, and cross sections of the cleared surface have been taken. The Contractor will not be paid for material taken from a borrow pit before it has been approved or before the pit has been staked out and cross-sectioned.

Borrow Excavation from a source outside the limits of the project which cannot be measured in its original position, is known as Foreign Borrow Excavation. When the Contractor wishes to use such material in an embankment, he must first obtain written approval for the District Engineer. Payment for Foreign Borrow Excavation* will be based on the volume measured in the completed embankment. Where Foreign Borrow Excavation is needed to finish a partially compacted embankment, cross sections must be taken both before and after the Foreign Borrow Excavation has been placed.

Selection of Pits

25. Borrow pits must be selected early enough to allow sampling and laboratory testing to be done before the material is needed. Representative samples from proposed borrow pits must be received in the laboratory at least 10 days before the date the test report is to be at the District Office. A sample of fine-grained soil must weigh at least 18 pounds; a sample of granular material must weigh at least 30 pounds. Samples must be identified on Form 447 and shipped in Department sample bags. If a test for the field moisture content is to be made, a representative portion of the sample must be tightly sealed in a friction-top can, which is put in the bag.

For each type of material in the borrow pit, there should be at least one sample for the first 5000 cubic yards of that type, plus one more sample for each additional 10,000 cubic yards or fraction of this quantity. Careful and constant inspection of material from borrow pits must be made to insure that the material does not change in classification or moisture content.

The District Soils Engineer will study carefully and test samples of every available source of borrow material. Inspection of the source must be thorough enough to identify different types of materials by color, texture, and other appearances. Samples of each type of material must be taken on the first visit to the source. Samples of different types must not be mixed.

Before material from a source of borrow or a cut area is sampled, existing project records and the soil profile should be checked to make sure that the source being considered has not been sampled and tested before. If test reports exist, their Laboratory numbers must be shown on the Form 447 sent in with the samples.

General Requirements of Embankments

26. To get a good job of embankment construction, the Inspector must be thoroughly familiar with the Special Provisions of the Proposal, the Contract Drawings, and the Specifications. If there is a difference in any of these, the wording of the Special Provisions governs. If the Contract Drawings show something other than required by the Specifications, the Drawings govern.

An embankment for a highway is not just a pile of dirt, but a structure* that supports the pavement. If any part of the embankment fails, the pavement will settle below the design grade. The pavement will have a rough riding surface, and it may even break up so it will have to be replaced. Every embankment must be placed on stable* ground. The embankment must be well drained. Each layer in a fill must be built of good material, compacted to the density required by the Specifications.

Most important, the moisture content* of the material must be controlled at all times. Too much moisture in any layer of an embankment will cause trouble during construction, and later on. Soil which contains a large amount of a fine-grained material, such as silt* or clay*, should always be placed in the embankment when its moisture content is below optimum; and it must not be allowed to absorb more moisture. If such a soil is too wet, it may possibly be compacted; but the compacted layer will become unstable when it is further compressed, or squeezed together, by the weight of the material laid on top of it.

During construction, an embankment must always be in condition to drain off rainwater before it has a chance to sink in. So that rainwater will drain quickly to the sides, the surface of the embankment must always have a high crown*, and each layer must be compacted to a smooth surface, without ruts. Special care must be taken to shape and seal any material that has been rolled with a sheepsfoot roller*. If it should rain while holes formed by this type of roller remain in the surface, a great deal of water might soak into the embankment. At each side of the embankment scupper ditches* should be kept open to drain the water to permanent or temporary ditches alongside. These ditches should carry the water away to an outlet.

Preparation of Original Ground

27. Before an embankment is started, the natural ground on which it is to be placed should be inspected carefully and brought to a uniform and firm condition. Any soft spots are likely to cause trouble at some future time. The weight of the embankment will slowly squeeze the water out of soft spots in the ground, and the ground will then settle. This type of settlement is called subsidence. Uneven subsidence will lead to failure of the pavement.

It is also necessary to prevent ground water from getting into the lower part of an embankment and causing a slide. If a spring or a soft spot in the ground shows up at the start of embankment work and no provision has been made for it on the Contract Drawings, the Assistant District Construction Engineer and the District Soils Engineer must be informed promptly. A system of subdrains* can then be laid out, and the necessary Extra Work authorized. Enough subdrains must be provided to drain water away from the ground surface.

Topsoil* should never be left in place under an embankment. Even a thin layer of topsoil can cause a bad slide in the embankment if the topsoil becomes wet. Unstable soil, such as muck*, peat*, and black swamp earth, must be removed from ground on which an embankment is to be placed. The Assistant District Construction Engineer and the District Soils Engineer will decide how much of this poor material must be dug out and disposed of. It is important that no unstable soil be overlooked. All holes left in the ground by the removal of unsuitable material should be filled with good embankment material fully compacted as required by the Specifications. If a hole gets filled with brush

and lumps of poor soil, the embankment over it may settle years after the fill has been placed. The natural ground is the foundation for the embankment, and covering up any fault is merely covering up future trouble. When the Proposal does not include a special provision for the removal of unsuitable material from the ground under an embankment, the Contractor will be paid for excavating such material as if it were Class 1 Excavation.

Placing Embankment Material

28. Embankments are built of soil, granular material, shale, rock, or random material as defined in the Specifications. Granular material is very good for use in an embankment under the following conditions: the embankment can be protected from flowing water; the granular material remains damp after it has been put in place; and there is enough fine soil material in it to act as a binder, but not enough to make it muddy. Embankment material, except rock, is usually placed in layers 8 inches thick before being compacted. Rock can be placed in layers not more than 2 feet thick (loose thickness). Backfill around a structure or pipe must be placed in 4-inch layers (loose thickness). The reason for 4-inch layers is to ensure good compaction. Also, the material next to a structure or a pipe should be graded from coarse to fine, so it will be hard for water to find a short path through the compacted material.

When placing embankment material, the Contractor should be warned to follow the lines set by the slope stakes* as closely as possible. If he places material outside these lines, he will not be paid for the extra material and, he will be responsible for any damage to private property caused by the increased width of the embankment.

Embankment Material Placed on Sloping Ground

29. Where an embankment is to be placed on a slope, benches* must be formed to prevent the embankment from sliding along the slope. The material excavated for benching should be used for the embankment, and the Contractor will be paid for handling it as if it were Class 1 Excavation. The Inspector-in-Charge must keep accurate records of the locations and volumes of the material excavated for benches. Benching details are usually shown on the cross sections. If enough details are not shown, the Inspector-in-Charge should find out from the Assistant District Construction Engineer where the bench limits are to be.

Frozen Material

30. It is not possible to fully compact* frozen material, and when frozen material thaws out, it may be too wet to be stable. The Specifications do not permit the use of frozen material in an embankment and no embankment material can be placed on natural ground, or on a layer of fill, that is frozen to a depth of more than 3 inches.

Need for Compaction of Embankment Material

31. To compact a material means to make the particles fit together snugly. When a material is fully compacted, the spaces between the particles are reduced to the smallest possible number and size. Proper compaction of embankment material is important and necessary for several reasons.

Compaction makes any material more stable. If the material in an embankment is not fully compacted furing construction, the weight of the embankment itself and the vibration of traffic will push the particles of material closer together. When this happens, the embankment will settle and the top surface will be uneven. This settlement will spoil the riding surface of the pavement or even break it up.

Some materials are mixtures of stone, gravel, or sand, with clay or silt in between the larger particles. If such a material is not fully compacted, enough water can get in the spaces between the particles to turn the clay or silt into liquid mud*. A slide in the embankment can result.

If the material in an embankment is not fully compacted, the spaces (voids) between the particles may be quite large. If these spaces fill with water and the water freezes, the expansion of the ice will cause the particles to move. This movement reduces the density of the material still more. When the ice melts, the settlement that follows may cause potholes in asphalt pavement or cracks in concrete pavement.

If any layer of an embankment becomes wetted by rainwater to above optimum moisture content* after it has been compacted, the material must be allowed to dry out and may have to be recompacted before more material is placed on top of it.

Protecting Compacted Material From Rainwater

32. Drying a soil that has become wet is always difficult. Water should not be allowed to stand in a cut or borrow excavation. The Contractor should use every means to keep water from collecting in pools on the surface of an embankment and soaking into the material. At all times during construction, the top of the last layer should be shaped and graded so that rainwater will drain off toward the edges. Also, the last layer should be fully compacted before work is stopped for the day, even though the operators of the compaction equipment may have to work overtime. A good way to seal the surface of a layer after it has been shaped is to roll it with a three-wheeled or tandem roller by starting from each edge and moving toward the center.

If the Contractor fails to shape and seal the surface of an embankment and there is a heavy rain, construction will be delayed. The water may soak into the embankment to a great depth. If more material is placed on top of the wet material, and the extra water and trapped air

is put under pressure, the material may move up and down, or pump, under the loads produced by heavy equipment. This pumping will prevent full compaction of the material.

REMEMBER
The draining of the top of partially completed embankment is important to the progress and quality of the construction. This provision of the Specifications must be enforced at all times.

Methods of Compacting Embankment Material

33. Equipment used for compacting embankment materials consists of several types of rollers, vibratory compactors, and tampers. The material can be compacted in one of three general ways.

One method is to force the particles together by pressure, just as a snowball is formed by squeezing snow in the hands. This method works best with a fine sticky material that contains a lot of clay or silt. Most rubber-tired and steel-wheeled rollers compact material in this way. The heavier the roller, the more the compaction.

Another way to compact embankment is by vibration. It is hard to compact broken stone or sand by squeezing the material. However, if some stone or sand is put in a can, and the can is shaken or tapped, the level of the granular material will go down, showing that the material has been compacted. The material can be compacted still more if a weight which has a flat bottom and will just fit inside the can, is placed on top of the material and the can is again tapped. Vibrating rollers and pan vibrators compact material in this way. Vibration works best with clean sand or stone that doesn't contain much sticky material, like clay or silt. The amount of compaction done by a vibrator depends on how many times the moving part vibrates in each minute, how far it moves each time, and how heavy it is. A certain combination of speed, distance, and weight will be best for each material. For this reason some types of pan vibrators or vibrating rollers will work better than others on a particular job.

The third method of compacting material is by tamping. Compaction by tamping is necessary in places where the material must be fully compacted, but a large piece of equipment cannot be used. Usually hand tamps, or tampers that work by air pressure, are used in such locations. An air-powered tamper strikes a large number of very hard blows in a short time, and can be counted on to give good results. Since the same number of blows are required to get the same amount of compaction, hand tamping takes much longer. A sheepsfoot roller also compacts soil by a type of tamping action and is sometimes called a tamping roller.

Rollers (See IV-18A,B,C)

34. Two types of steel-wheeled rollers are three-wheeled rollers* and tandem rollers*. Both kinds are made in several machine weights, and any roller of either kind can be made heavier by ballasting, that is, adding weight by filling the rolls with water; sand and water; or calcium chloride solution. The wheels of some three-wheeled rollers can be loaded very heavily by clamping cast-iron weights to their spokes.

Three-wheeled rollers will do a good job of compacting almost any material if the layer of material is thin enough. The roller must be so ballasted that it will produce the most compaction possible without breaking up the particles of material or causing the material to squeeze out from under the rolls. It is sometimes necessary to roll first with a light roller and then with a heavy roller.

Tandem rollers are usually used for smoothing out the surface of a layer of material. When they are used for compaction the wide rolls "ride up" on hard spots in the layer, and the material in between may not be fully compacted to uniform density.

Rubber-tired rollers* are made in a large range of weights, and also can be ballasted. The tire pressure can also be changed. In general, the heavier the roller, the greater will be the thickness of the layer it can compact fully. A higher pressure will result in higher density at the surface of the material. By changing the amount of ballast and the tire pressure, it is possible to adjust the pressure on the contact area to suit conditions. A rubber-tired roller aids compaction by its kneading action; that is, the particles of material are moved slightly so that they fit together more snugly. For this reason, a rubber-tired roller sometimes leaves slight grooves or marks on the surface of the layer being compacted. This is on the surface of the layer being compacted. This is a sign of good compaction, but if material is squeezed out from under the tires, the roller weight or tire pressure should be reduced.

Grid rollers are classed between steel-wheeled and sheepsfoot rollers. They are used to break up lumpy material. They are also used ahead of, or instead of, a sheepsfoot roller when compacting some materials.

A sheepsfoot roller has many lugs, each of which is shaped like a sheep's foot and has a small contact surface. Sheepsfoot rollers are built in many sizes, and may be ballasted up to 18 tons or more. Because of the shape of the lugs, the contact pressure on the soil is very high. Sheepsfoot rollers are good for compacting most types of soils that are not too granular, but a great many passes are needed to get complete coverage and to do a really good job. They work best with fine-grained material. In such a material they have the advantage of compacting a layer "from the bottom up" until the feet "walk out", where a steel-wheeled roller might just compact the surface.

Vibratory Compactors

35. There are two general types of vibratory compactors; vibrating rollers and pan-type vibrators. In a pan-type vibrator, the vibration is applied to the layer being compacted by a steel plate or shoe. Either type of vibratory compactor does a good job of compacting granular material, such as sand or crushed stone; but neither works well when the layer being compacted contains more than about 15 percent of silt or clay. Vibrating compactors can compact thicker layers of granular material than can other types of compactors. However, the number of vibrations per minute must be within a certain range, which depends on the depth of the layer and the kind of material being compacted. The best speed of vibration is usually between 1200 and 4500 vibrations per minute. To get the best job of compaction in the shortest time the right speed must be found by experiment.

Tampers

36. Mechanical tampers do a good job of compacting granular materials. Where hand tampers must be used, the compaction operation should be inspected continuously. It takes at least ten times as long for a man with a hand tamper to get the same amount of compaction as a man with a mechanical tamper. Also, a man using a hand tamper is likely to get tired quickly and he soon goes through the motions of tamping without really compacting the material.

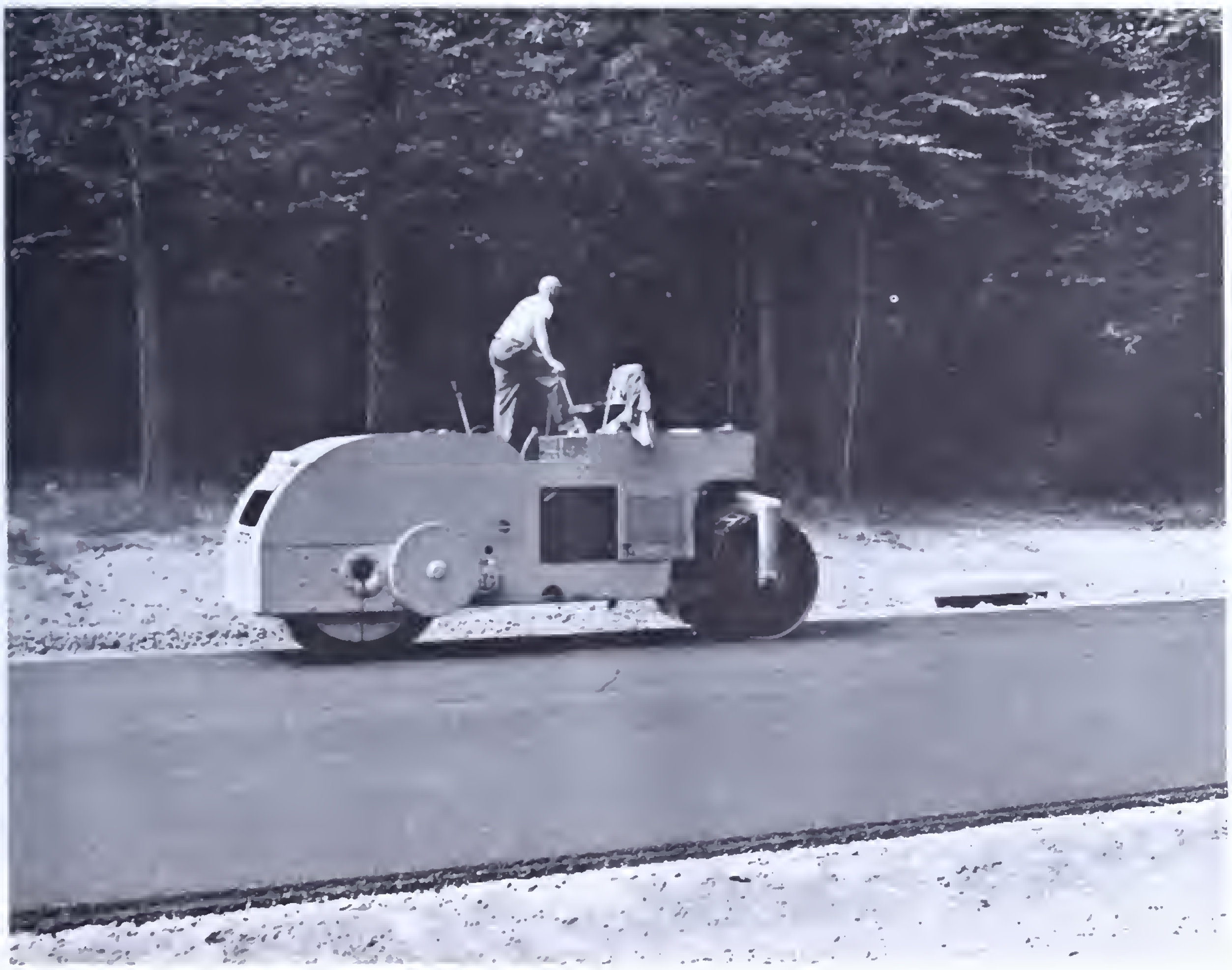
Incidental Compaction by Other Construction Equipment

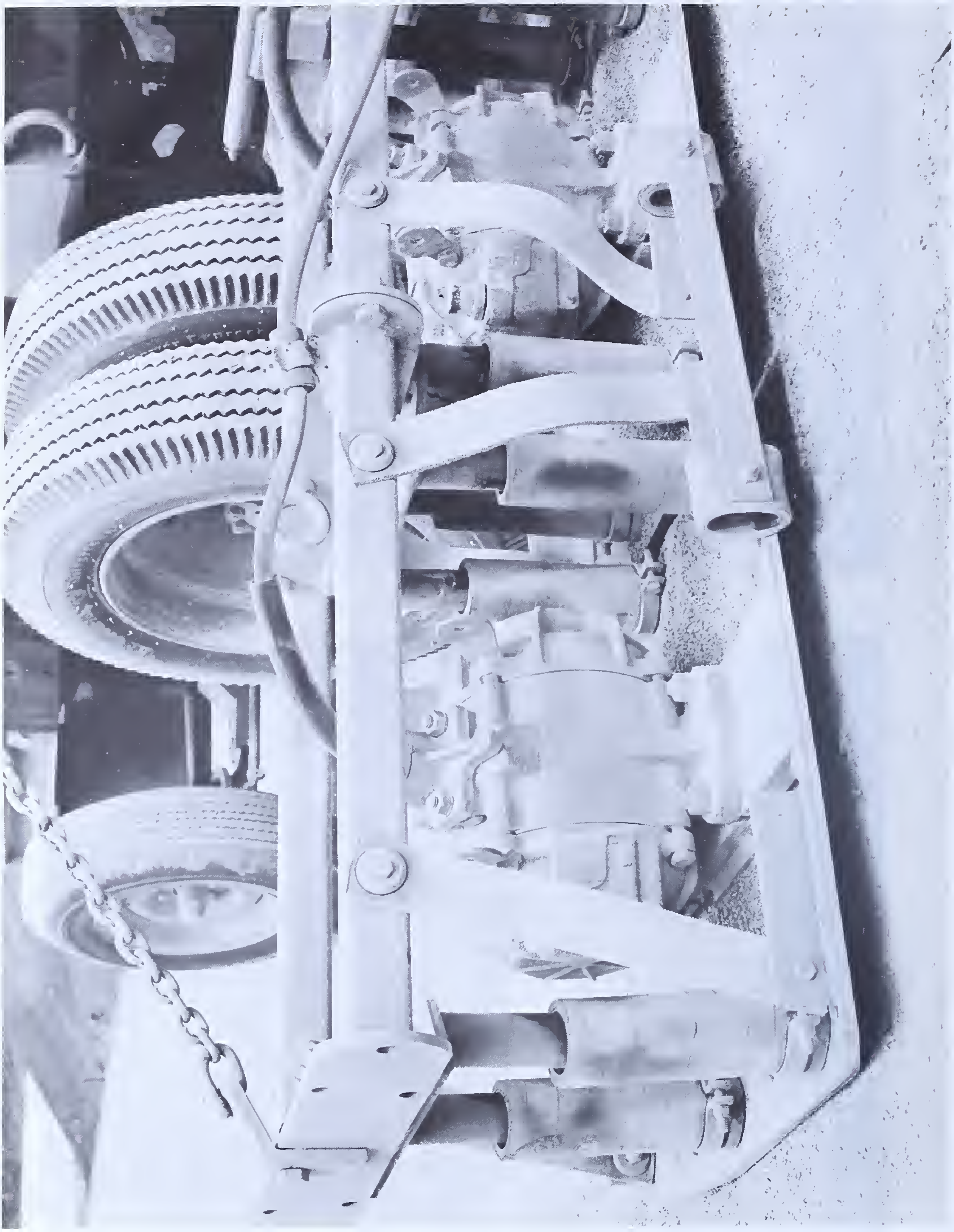
37. Much compaction is produced by construction equipment working on the embankment. Bulldozers will compact sandy material, and heavy rubber-tired equipment will compact most materials. For such equipment to do the most good, it must cover the entire width of a layer uniformly, from edge to edge, and must not follow one path. If all the equipment follows the same track, the material in the ruts will be compacted to a high density before the rest of the layer is rolled. It will then be impossible for the rollers to produce uniform density between the ruts. Unless special attention is given to operation of the hauling and compacting equipment, the edges of the embankment will not be as well compacted as the center. To prevent shoulder settlement and embankment slides, the Inspector must make sure that the whole embankment, from top to bottom and from edge to edge, is uniformly and fully compacted.

Responsibility For Obtaining Stable Embankments

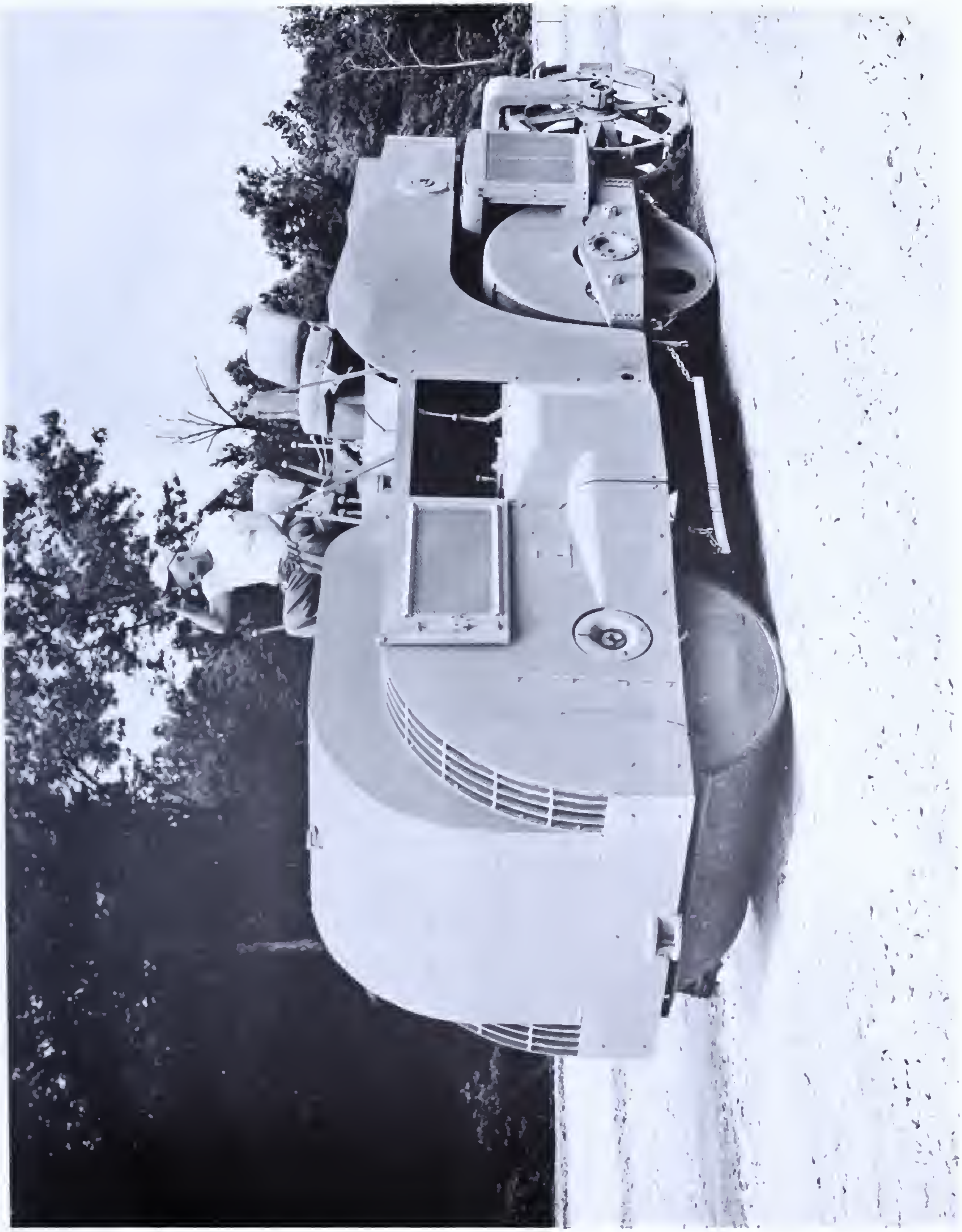
38. The Contractor is responsible for obtaining stable embankments. The material must not be put in place faster than it can be fully compacted, in accordance with the Specifications. All required compaction equipment must be on the job before any embankment is started.

Three wheel roller


Tandem roller



Pantype vibrator



Vibrating roller

Subbase

The paths followed by earth-carrying equipment on the embankment during construction should be spread over as much of the width of the embankment as possible. One of the pre-construction items is to make sure that the Contractor understands this is to his advantage.

Compaction Next to Structures and Over Pipe Culverts

39. The Inspector must pay special attention to the placing and compaction of embankment material next to structures, over pipe culverts, and in places where rollers cannot be used. Settlement usually occurs in such places unless great care is taken in compacting the fill material. Density tests should always be made on compacted material near the edges of embankments, and in other locations where compaction may not be thorough.

Granular material* or rock must be used for the fill in back of any bridge abutment. If such material is available, it should also be used for fill over pipe culverts and in places where large compaction equipment cannot operate. Where Class 2 or Class 3 Excavation is necessary to provide space for a structure, granular material must be used for the backfill.

The granular material for the fill behind a bridge abutment should start at the level of the top of the abutment footing, or the natural ground near the footing, and should extend back from the abutment for a distance equal to twice the height of the abutment. All Class 2 and Class 3 excavation for structures must also be backfilled with granular material. The reasons for using compacted granular material are to get good drainage and to prevent future settlement as much as possible. Particles of granular material or rock fragments larger than 3 inches must not be used in back of an abutment or in places in which rollers cannot operate. This size limit applies also to any material that must be placed in 4-inch layers and compacted with mechanical tampers.

Importance of Moisture Content

40. The amount of water in a soil, or soil mixture, shown as a percentage of the dry weight, is called the moisture content*. Each soil, or soil mixture, compacts most easily, and to its highest density at some definite moisture content. This is called the optimum moisture content. A mixture of granular material and a sticky material, such as clay or silt, compacts most easily when the moisture content is within a narrow range. The range of moisture depends on the type of material and the method used to compact it. Very fine materials, such as silt or clay, must have just the right amount of water in them to be fully compacted by any kind of equipment.

Unless the Contractor gets the written approval of the Engineer, soil containing too much moisture cannot be used in an embankment until it has been allowed to dry. The moisture content of the soil, before it is compacted, must not be more than 2 percent above the optimum moisture content shown by a laboratory test.

Changing Moisture Content

41. Moisture may be added to embankment material by the use of sprinklers. The Contractor will choose the type of equipment used to spray on the water, but it must be approved by the Assistant District Construction Engineer. A simple method is to mount a tank with a spray-bar on a dump truck. The amount of water sprayed on the soil can be controlled by raising or lowering the truck body, and by changing the speed of the truck. Another way of adding moisture is to blend wet soil with dry soil, but such blending may complicate the method of hauling the materials and may require so much equipment time that it is impractical. It may be cheaper for the Contractor to buy and haul in suitable borrow material at his own expense. In any case, the added moisture must be mixed and blended uniformly with the soil. The use of a combination of drag equipment, discs, graders, or tamping rollers will give good results.

Drying of wet soil may be speeded by the use of discs or other equipment that will turn the material over and expose it to the air.

Soil Density

42. The <u>dry density</u> of a soil is the weight, in pounds, of a cubic foot of the material after the weight of the water in the soil has been subtracted. The <u>maximum dry density</u> of a soil is the highest dry density found by a Laboratory test. Soils, and soil mixtures, are compacted on the grade to some dry density. This dry density is compared to the maximum dry density obtained in the Laboratory to find the <u>percentage</u> of maximum density that has been produced by the field compaction.

The soil is compacted in the Laboratory by a method called the Standard Proctor Test. By this method the soil is compacted to a dry density that should be obtained on the job with a reasonable amount of rolling at the right moisture content. For most types of construction the Specifications require that the material on the job be compacted only to some percentage of the maximum dry density* obtained by the Standard Proctor Test. This percentage is found by dividing the dry density of the soil in the construction by the maximum dry density obtained by the Standard Proctor Test and multiplying by 100.

Test For Maximum Density

43. To find the percentage of maximum laboratory dry weight being obtained by compaction in the embankment, it is necessary to know the maximum density and optimum moisture content for each type of soil to

be placed. The maximum density and optimum moisture content are usually found by tests made on samples sent to the Laboratory at the time the soil survey is made. A field check should always be made to check these values, especially if the soil does not have the same amount of fine material in it as the Laboratory tested sample. In case the type of soil is different from the type sampled and tested, its maximum density and optimum moisture content must be found by tests made in the field Laboratory before it is possible to determine accurately the percentage of maximum density.

Field Density Test

44. The field density test is a standard test made to find the dry weight of a known volume of soil. A sample is removed from the compacted layer, carefully weighed, and its moisture content measured. The volume of the hole left after the sample was removed is then found from the volume of standard dry sand required to fill the hole. Knowing the weight and volume of the removed soil, and its moisture content, the dry density of the sampled soil can be found.

The standard test is intended for use on soil that has at least 35 percent passing the No. 200 sieve. It can be used as a guide for the finer-grained granular materials, but is not accurate enough for shale, random material, or rock. It does not give reliable results in materials other than soil and the finer granular materials, because the hole is so rough on the inside that the volume cannot be measured accurately.

The standard method of test for density of soil is AASHO Designation T147, Method A, modified, or changed somewhat, for the use of the sand-cone density apparatus. Procedures for calibrating the sand-cone density apparatus and the sand used, are given in Supplement No. 1 to Bulletin No. 39, revised January, 1958. Instructions for making the test and computing the results are given in Chapter XI of this Manual. Test results are to be reported on Form 478, Report on Embankment Compaction, revised August 26, 1957.

Use of Density Tests

45. Enough density tests must be made to be sure that the specified percentage of laboratory density is being obtained in all parts of an embankment. Unless otherwise directed, there should be at least one test for every 1000-foot length of layer put in place. If the testing would interfere with the Contractor's operations, a layer should be constructed in two sections, each section covering half the width of the embankment. Check tests should be made on parts of the layer which may not be getting enough compaction, such as the area near the edges of the embankment, or at places where the compacting equipment is turned around.

The results of the field density tests must be compared with the requirements of the Specifications. The minimum requirements depend on the maximum laboratory dry weight of the soil and on the height of the

embankment. The report for each density test must show the total of the embankment to the layer tested; and the minimum compaction requirement. Comparison of the density obtained in the field with the required density may show the need for more compaction. If the layer must be re-compacted and retested, a note of explanation must be included on the density report.

Compaction to Required Density

46. If too many passes of the compaction equipment are needed to get the required density, the Contractor may want to try one or more of the following methods of reducing the amount of rolling required:

(1) reducing the depth of each layer;
(2) using heavier compaction equipment;
(3) using a different type of compaction equipment;
(4) adding more moisture;
(5) reducing the moisture content of the material by drying and rehandling it.

Shrinkage

47. Shrinkage is the decrease in volume which takes place when excavated material is placed in an embankment. Causes of this shrinkage may be: (1) the density of the soil is greater in the embankment than in its natural conditions; (2) material is lost in the haul; (3) material is lost by scalping that is required to remove sod or root mat; and (4) subsidence (settlement) of the embankment foundation occurs. Considerable shrinkage may occur on a project where the cuts are shallow and a great deal of scalping is required. Little or no shrinkage will usually occur on a project where the cuts are deep or the excavated material is bedrock. Shrinkage is taken into account in the earthwork quantities used in the design, and in Borrow Excavation. Since Foreign Borrow Excavation is paid for in place, no shrinkage or subsidence is calculated.

Losses of material due to scalping and to hauling are estimated from records of other jobs. Where soft material has not been removed completely, losses caused by subsidence can be estimated from the results of laboratory tests made on the foundation soil. These are called consolidation tests and are usually made only in the case of high fills.

The shrinkage resulting from increased density in the embankment may be estimated by comparing the average density of the soil in its natural condition before being excavated and that of the compacted material. The shrinkage resulting from increased density in the embankment may be computed as follows:

Percent of shrinkage in embankment $= \left(\frac{A}{B} - 1\right) 100$,
where,

A = average dry density of compacted soil in embankment, expressed as a percentage of laboratory maximum dry density.

B = average dry density of the soil in its natural condition, expressed as a percentage of laboratory maximum dry density.

Finished Grade

48. On a length of roadway where grading only is required, the finished grade between the outer limits of the shoulders must be within 0.2 foot of the position shown on the Contract Drawings. The average grade line must be close enough to design grade that the grading quantities are not changed and the cost of the construction is not increased.

On a length of roadway where base course, pavement, or subbase is to be placed, the Contractor must fine-grade accurately to the grade line and cross section shown on the Contract Drawings. Next to a curb, the grade can be changed from that on the cross section shown on the Contract Drawings only to obtain satisfactory drainage and when the Assistant District Construction Engineer approves the change.

Preparation of Subgrade

49. The subgrade is defined in the Specifications as the bottom of the excavation and the top of the embankment between the outer limits of the base course, pavement, or subbase, when it is completed as specified. However, the term "subgrade" usually includes the part of the roadbed some distance below the surface of the subgrade. The surface of the subgrade must conform to the limits, grades, and cross sections shown on the Contract Drawings. The preparation and compaction of the upper 6 inches of the subgrade is very important, because it is the foundation for the subbase, base course, or pavement. Smooth appearance is not the only requirement of a good subgrade. If it does not have enough strength or bearing capacity, to give uniform support to the subbase, base course, or pavement, failure of the pavement can be expected. The Inspector must make sure that the material in the subgrade has been fully compacted to the required density for its full width, and that it does not contain any objectionable material.

The Specifications give definite directions as to how to prepare the subgrade under different conditions. The correct way depends mainly on the type of base or pavement that is to be supported by the subgrade. In general, to make grading easy and to have the subgrade give uniform support, it is necessary to break up and remove all large pieces of loose rock, boulders, and rock ledges.

Required Condition of Subgrade

50. The moisture content of the subgrade material at the time of compaction must never be more than 2 percent above the optimum moisture content. However, the moisture content must not be any more than optimum for granular materials containing more than 15 percent that will pass the No. 200 sieve; for silt or a sandy-silt soil; or for any other material that yields under the loads from construction equipment.

Sometimes the subgrade can not be made stable enough by controlling the moisture content and compacting the upper 6 inches, as specified. In such a case, the material must be excavated to such a depth that, where it is replaced and recompacted at a moisture content equal to or less than optimum, the upper 6 inches will have the required stability. The excavation of unsuitable material that must be removed from below the subgrade surface in a cut will be paid for as Class 1 Excavation. When unsuitable material must be removed from the top of an embankment, the work must be done at no expense to the Department.

Sometimes, after a cut or fill has been completed, parts of the subgrade become soaked with water because the Contractor did not do the grading work necessary to drain the water. Before the subgrade will be accepted, the Contractor must remove the soaked material, replace it with material having the right moisture content, and recompact it, at no expense to the Department.

When concrete pavement is to be placed directly on the subgrade, the Contractor must furnish and use a standard subgrade tester to check the surface of the subgrade as soon as fine grading is completed.

When a base course for a flexible pavement or a subbase is to be placed on the subgrade, the entire width of the subgrade must be checked for crown and grade by the use of crown templates, straightedges, and string lines.

Enough subgrade drains must be put in to allow water to escape from the subgrade. Trouble often results because the drains are not built so that the water can get out through a shoulder, or because drains under shoulders become clogged during construction.

Additional Width of Subgrade For Setting Forms

51. For a base course or pavement where side forms are to be used, the subgrade must be graded and compacted for an additional width of 24 inches outside of each form line. Payment is made, however, only for that portion on which the pavement or base course is placed. An additional 24-inch width also must be graded and compacted during the preparation of the subgrade under a subbase which does not extend far enough to drain through a shoulder. Such a condition usually occurs next to an unpaved median area or on the high side of a superelevated curve.

Required Length of Prepared Subgrade

52. The Contractor must always have enough subgrade ready so that there will be working space for checking the lines and grades, and for making corrections in case the material must be scarified or replaced and recompacted. For one-lane construction, the length of graded subgrade ready for checking must be at least 750 feet. For two-lane construction a length of not less than 500 feet must be ready. The Contractor must protect the prepared subgrade during paving as required by the Specifications.

Material for Subbase

53. A subbase is a layer of material used to drain water from beneath the pavement; and to spread each wheel load over the subgrade. It is usually built of granular material. Its thickness depends on the kind of subgrade material, and the kind of traffic to be carried by the highway.

To be suitable for use in a subbase, granular material must be durable, free from objectionable materials, and well graded. These requirements of the Specifications can be met by a wide range of materials, and suitable material can be obtained from a local source. However, before material from any source is used in a subbase, the source must be approved by the District Soils Engineer. Also, the quality of the material must be controlled during construction.

Shale should never be used in a subbase. Granulated slag from a blast furnace may be used if the source is approved and no particles are larger than 2 inches in diameter.

Material used in a subbase should not contain lumps of clay or silt, or particles of soft stone which will break up during the spreading and compaction and increase the amount of very fine material in the subbase. If even a small volume of such unsuitable material is included, the subbase as finally constructed may not meet the Specifications and may become soft and unstable when wet.

Also, fine material in the subbase may lead to frost boils* forming in winter. These frost boils frequently cause pot holes* in flexible pavement, and heaving of concrete pavement.

If pit-run or run-of-bank material contains lumps or masses, they must be broken down before the subbase material is delivered to the project.

A change in the source of material may be made only with the written permission of the District Engineer. A mixture of materials from two or more approved sources may be used in a subbase, provided the materials are blended before they are placed on the subgrade. The mixture must be uniform and meet all requirements of the Specifications.

Sampling and Testing Subbase Material

54. Samples from a possible source of subbase material must be taken soon enough to allow testing and approval of the source before the material will be needed. The number and size of samples to be taken for advance approval of the source must be large enough to represent the entire source. There should be at least one sample for the first 5000 cubic yards taken from the source, and another sample for each additional 10,000 cubic yards or fraction of this quantity.

After a source has been approved, the Inspector must take continuous checks to be sure that the material delivered to the project daily is uniform. For such checking, a sample weighing about 25 pounds should be collected by taking several small samples, each weighing about 5 pounds, from different trucks.

If a truck load of material contains lumps of clay or silt, or of clay-sand-gravel mixture, these materials must be included in the sample in the same proportion as they occur in the truck. The lumps must be broken up as the sample is taken and prepared for testing. It is important that none of the lumps be thrown away and none of the very fine material (mostly clay and silt) be lost. These fines have a great effect on the quality of the material which must be truly shown by the test results.

A test should be made to determine the gradation of the material, and the entire sample washed to find out how much of the material passes the No. 200 sieve.

> REMEMBER
>
> The percentage passing the No. 200 sieve must not be greater than that allowed by the Special Provisions of the Proposal or by the Specifications.

In addition to the samples for field tests, it is necessary to send samples to the Laboratory for check tests. One sample should be taken for each 5000 cubic yards removed from the source and used on the project.

Control of the proportion of smaller particles is most important. The right amount of the material passing the No. 10, No. 40, and No. 200 sieves makes possible good drainage and good compaction, which are necessary if the subbase is to serve its purpose.

Construction of Subbase (See IV-18 D)

55. The subbase must be constructed exactly as described in the Specifications. Uniform mixing, the addition of the necessary moisture, and thorough compaction by rolling should be given special attention.

The subbase material must be placed on the prepared subgrade with the least possible segregation* of coarse and fine particles. To reduce segregation the material should be spread by the use of a spreader-box. If the subbase material is dumped on the subgrade directly from trucks, the Contractor must move the whole pile of material during the spreading operation. He should not be allowed just to level off the pile. Moving all the material is necessary to get uniform compaction, and prevent hard spots in the subbase.

Since the subbase is an important part of the pavement structure, care must be taken in selecting, placing, and compacting the subbase material. Careless or improper construction of the subbase may cause expensive maintenance and, possibly, early failure of the entire pavement.

Filling low spots in the subgrade with the porous subbase material cannot be allowed, because the surface of the subgrade should be sealed, and not be porous. The surface of the subgrade must always be so shaped and so dense that water will run off to the edges.

Controlling Thickness of Subbase

56. To give uniform support to the base course or the concrete pavement, the subbase must have uniform thickness, as well as being made of uniform material and rolled to uniform density. Control of subbase thickness starts with the preparation of the subgrade. The subgrade must be fully compacted and then brought to grade before the subbase is placed on it. The Specifications require that the subgrade be checked in the same way as specified for checking the finished surface of base course, using approved templates, straightedges and string lines. At any point where the subgrade is too high or too low, the subbase placed on it will be too thin or too thick. If the subgrade has not been fully compacted at any spot, its surface will be pushed down at that spot to form a pocket when the subbase is rolled. Water will collect in the pocket and weaken the pavement structure.

Subbase material should be spread thick enough to bring the compacted surface slightly above its finished grade. Fine grading of the subbase should always be a trimming operation.

After enough subbase material has been spread to a uniform depth for the entire width, including the extra 2 feet on each side where forms are to be used, the moisture content should be checked and water added if necessary. Since subbase material is mostly granular, it is best to have the moisture content one or two percent above optimum moisture rather than below optimum. Care must be taken to apply water uniformly and not get too much in one place where it might soften the subgrade.

As soon as the subbase material has been mixed, brought to the proper moisture content, and spread roughly to a uniform thickness, compaction by rolling should be started. It is best not to prepare portions of subbase much more than 750 feet long for one-lane construction, or 500 feet for two-lane construction, because the moisture content may change before rolling of a greater length can be completed. Also, the subbase material may become rutted and dirtied by construction equipment.

Three-wheeled rollers and heavy rubber-tired rollers may be used to compact the subbase. First rolling is usually done with the three-wheeled roller, starting at the outside edges and working toward the center. There should be a regular rolling pattern in which the rear wheel of the roller overlaps its previous path by about half its width. This rolling "sets" the subbase material and prevents movement during the rest of the compaction.

In addition to the first rolling, the subbase must be given more rolling with three-wheeled rollers, and approved heavy rubber-tired rollers, or vibrating rollers so that it is uniformly compacted to the required density. If all the compaction is done with steel-wheeled rollers, a crust may be formed at the top of the subbase while the material at the bottom is not fully compacted. Final rolling should be done with a three-wheeled or tandem roller working from the outside edge of the subbase toward the center.

The thickness of the subbase should be checked frequently by digging small test pits about a foot in diameter through the subbase to the subgrade. Care must be taken not to disturb the surface of the subgrade. A short straightedge should be placed across the hole, and a measurement taken at the center of the test-hole from the bottom of the straightedge to the subgrade. This measured thickness must always be greater than the required thickness of the subbase when concrete pavement is to be placed on the subbase, and must be between the limits set by the Specifications when flexible pavement is to be built.

Checking Density of Subbase

57. When compaction tests are being made, the condition of the subbase material should be observed and recorded. While the test-hole for checking the in-place density is being dug, it is easy to see if the subbase is harder and more dense at the top than at the bottom. Where the compaction is not uniform, the condition should be brought to the attention of the Inspector-in-Charge or the Assistant District Construction Engineer. The results of tests for in-place density show only the average density of the subbase layer.

Use of Shoulders

58. A shoulder is the portion of the roadway between the pavement and the nearer edge of the ditch or side slope. One purpose of a shoulder is to furnish side support for the pavement. On highways carrying heavy

traffic, shoulders should be built which will be stable in all kinds of weather, and on which a vehicle can travel safely in an emergency. The widths of shoulders must not be less than those shown on the Contract Drawings. The shoulder material must be compacted and its surface shaped so that water will be drained away from the pavement. If necessary, subgrade drains should be installed before the shoulder material is placed. Also, it may be necessary to provide for drainage of the subbase through the shoulders. Wherever the width of the right-of-way will permit, and excess excavated material is available, shoulders should be widened uniformly in certain locations. Shoulders may be widened on the inside of a curve or on an embankment where guard fence may be required. Work of this type will be under the control of the Assistant District Construction Engineer, who will make sure that the side slope will not be overloaded and cause a slide. Also, where widening the shoulders would bring the edge of a side slope outside the limit of the right-of-way, approval for the widening must be obtained from the Assistant District Construction Engineer.

Construction of Ordinary Shoulders

59. Where it is not necessary to use side forms to build the base course, the shoulders must be built to their full width and to the level of the top of the base course at the time the subgrade or the subbase is prepared. This procedure is used where the base course is of a flexible type. These shoulders are to be compacted with a 10-ton roller before they are cut to the correct line and grade for the edge of the base course. Additional material and finishing will be required after the wearing surface has been placed. To prevent water from collecting between the shoulders when they are built ahead of the base course, trenches must be dug through the shoulders. The Contractor will not get separate or extra payment for this work, because he is responsible for drainage of the subgrade.

When side forms must be used to build the pavement, work on the shoulders cannot be finished until the forms have been removed. However, the shoulders should be shaped and compacted as soon as possible after the base course or pavement is completed. A roller weighing between 3 and 6 tons must be used for compacting a shoulder next to a concrete pavement. If the thickness at the edge of the pavement is 10 inches or more, the shoulder should be built in two layers, because the material cannot be fully compacted in a single layer. Care must be taken not to damage the concrete.

If the material used for the shoulders consists of broken macadam or other coarse particles, it is necessary to mix some earth, shale, or other binder with the coarse material in the top layer to prevent raveling of the surface under traffic.

Construction of Stabilized Shoulders

60. A stabilized shoulder must allow water to run off the surface of the pavement without washing material out of the shoulder so that gullies are formed. The shoulder material must be of a type that will not shrink away from the edge of the pavement.

The material for a stabilized shoulder must come from an approved source and must be placed in two or more layers. The compacted depth of the top layer must be 3 inches, and the compacted depth of a lower layer cannot be more than 7 inches. For the lower layer, or layers, the material may be durable natural granular material, or granular particles mixed with sand, stone dust, soil, or other filler. The largest particles in the material for the top layer must not be more than 2-1/2 inches in size. If the top layer does not remain stable, because material is washed away or ravels under the action of traffic, it is necessary to add a binder. The binder may be clay, or clayey soil, and must be mixed uniformly with the larger particles.

Granulated blast furnace slag will not be permitted in the top layer. Granulated slag does not have good binding action and takes a long time to set up and make a strong shoulder.

Shaping the subgrade for the standard stabilized shoulder is usually done with a motor grader, often with a special blade. The required density of the rolled subgrade depends on the kind of soil being compacted. A trench roller is usually best for rolling the subgrade for the shoulder. However, other types of compaction equipment may be used. A template must be used to check the cross section of the subgrade against that shown in the Contract Drawings.

After the subgrade is shaped and compacted, material for the stabilized shoulder is spread on the prepared surface in layers. Any approved equipment may be used for the first compaction of this material. For final compaction of the top layer, three-wheeled power-driven rollers or tandem power-driven rollers meeting the requirements of the Specifications must be used. The material must be compacted to the required density as shown by field tests. However, if the density cannot be measured by a field test, the Assistant District Construction Engineer will decide when rolling may be stopped. If the material is rolled until there is no further movement of the material under the roller it may be considered to be fully compacted.

Where large compaction equipment cannot be used, the shoulder material must be compacted to the required density by means of mechanical tampers.

CHECK LIST OF IMPORTANT ITEMS

CLEARING AND GRUBBING; EARTHWORK; SUBBASE; AND SHOULDER CONSTRUCTION

Has Contractor submitted plan of operation?

Has Contractor's equipment been tested?

Has Contractor obtained written permission for use of property from owners?

Have plans been made for protection of all important monuments, corners, benches and markers?

Has Assistant District Construction Engineer approved location of topsoil stockpiles?

Have satisfactory arrangements been made to protect all valuable trees?

Have property owners been notified of construction that will affect them?

Has Contractor made arrangements for legally burning or satisfactorily disposing of waste material?

Has the Roadside Development Engineer been consulted as to the removal of any large trees whose roots will be affected when cuts are made?

Have slope stakes been set for Clearing and Grubbing?

Have the Special Provisions, the Contract, the Specifications and the Drawings, been checked to make sure that all other pre-construction items have been taken care of?

Has Contractor placed guard stakes for all construction stakes?

Is Contractor promptly refilling all holes left by removal of stumps or poles with the proper material, fully compacted, to prevent water pockets?

Are all necessary measurements of excavated material being made and recorded?

Is Contractor constructing sufficient permanent and temporary drainage to take care of heavy rains?

Are side slopes being cut as shown on Drawings?

Are Contractor's grading operations within proper limits?

Has written approval been obtained from property owners whose driveways will be affected?

Have borrow pits been located and material sampled?

Has ground that will be the foundation for embankments been inspected and prepared?

Has drainage been put in to take care of ground water?

Has Contractor been instructed as to placement of material between slope stakes, routing of construction equipment, and sealing and drainage of embankment surface?

Have arrangements been made for orderly placing of lifts only after layer on which they are to be placed has been checked for density and moisture content?

Is subgrade being brought to proper grade and width? Compacted for full width, including extra 2 feet on either side, if concrete pavement is to be constructed?

Has subbase material been approved by District Soils Engineer? Are a sufficient number of samples being taken?

Are check tests being made to make sure that there is not too much fine material in the subbase after placing?

CHAPTER V

PIPE CULVERTS AND DRAINAGE

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Effects of Water on Soil

1. The general purpose of highway drainage is to get water away from the road as fast as possible, so that it will not soak into and weaken the subgrade*, an embankment*, or a subbase* or base*. Any soil or soil mixture used in highway construction is stronger when dry than when very wet. A certain amount of moisture is needed to get good compaction of soil during construction. However, if compacted* soil becomes soaked with water, it will lose its firmness. As a result, it may not provide enough support for the pavement, or there may be a slide or caving in of an embankment* or a side slope* in a cut*.

Some kinds of soil swell* when they get wet. Such swelling will often lift up and cause a bump in the roadway. Water in any kind of soil can cause a great deal of trouble if it freezes. Since ice takes up more space than did the water from which it is formed, the pavement is raised when the water freezes. When the ice melts, holes filled with water and mud are left in the soil below the pavement. The weight of traffic then may cause breaks in the pavement. The pot-holes* so often seen in roads and streets in the spring of the year are the result of the freezing and thawing actions in the soil. The right kind of drainage can keep water from collecting under a pavement. The pavement will then remain well supported and the cost of maintenance will be reduced greatly.

Surface and Subsurface Drainage Systems (See V-16A)

2. Highway drainage systems are of two general types: surface and subsurface. A surface drainage system is provided to permit rain as it falls, and snow as it melts, to run off the roadway surface as rapidly as possible and to lead this water away from the highway so that it will not soak into the soil. Included in the surface drainage system are roadway crowns; curbs and gutters; drop inlets; storm sewers and storm drains; ditches; and culverts.

The purposes of a subsurface drainage system are to cut off water from springs, or seepage through the natural soil, before this water can get under the pavement, and to carry away any water that gets into the soil under the pavement through joints or cracks in the pavement or through the shoulders. Passageways in a subsurface drainage system are commonly called underdrains, subdrains or pipe drains. An underdrain may be built of pieces of stone or a mass of granular material, such as sand or coarse aggregate. If a lot of water has to be taken care of, a pipe drain is used. A pipe drain must be so constructed that water can get into it through its wall or open joints. It may be made of porous* concrete, clay, or metal pipe with perforations (small holes) through its wall. The pipe usually is laid in a bed of pervious* material called a filter, which keeps fine soil from being washed into the pipe through its wall. If much soil gets into the pipe, the pipe may become plugged. A loss of the soil may leave a hole under the pavement, which would then settle.

NOTE: Words marked with an (*) are explained in a word list at the back of this book.

Changes in System Shown on Contract Drawings

3. The kinds, sizes, and locations of the parts of the drainage system needed for a particular highway depend a great deal on the actual field conditions. The design office usually plans a proposed drainage system from survey notes long before work is begun on clearing and grubbing. This system is shown on the Contract Drawings. Because of conditions found to exist during construction, however, the system originally designed may not be satisfactory and changes may be needed. The Inspector must keep in mind the importance of good drainage. He should study the drainage conditions from the time he first arrives on the job, before work on clearing and grubbing is started, until the project is completed. If he believes that a change should be made in the system shown on the Contract Drawings, he should bring the matter to the attention of the Assistant District Construction Engineer.

The required size of a culvert for carrying water through an embankment depends on the area*, slope*, and condition (as cultivated, wooded or grazing land) of the ground from which water runs to the culvert. Filling in a low spot in the ground, even some distance from the highway, may cause an increase in the area of land surface drained by a certain culvert. Or, grading* and paving* a large area near the culvert, as for a parking lot, may cause the water to run off that area much faster than it did when the drainage system was originally planned. To prevent water from backing up at the culvert and flooding the highway or nearby property, a larger culvert may be needed.

Springs often flow only during certain times of the year or after heavy rains. An underground flow or seepage of water is often discovered for the first time during excavation for the highway, probably after a heavy rain. Quite often, people who live near the project can give an Inspector useful information by telling him about general drainage conditions and high water levels in the neighborhood at certain times of the year.

It is part of the Inspector's job to watch for or find out about any condition that may affect the design of the drainage system and to inform the Inspector-in-Charge. The Inspector-in-Charge should check the information and pass it on to the Assistant District Construction Engineer as soon as possible, so that any necessary changes can be made in the drainage system with the least expense and the least delay to the Contractor.

Materials For Pipe Culverts

4. A culvert is a drainage structure having an opening 8 feet or less in width.

The openings in culverts may have different shapes. However, round pipes are used most often for culverts, and only pipe culverts will be discussed in this chapter. The possible kinds of pipe culverts are as follows:

Cast-iron pipe, heavy cast-iron pipe, or extra heavy cast-iron pipe.

Reinforced cement concrete pipe or extra strength reinforced cement concrete pipe.

Vitrified clay lined reinforced cement concrete pipe or extra strength vitrified clay lined reinforced cement concrete pipe.

Corrugated metal pipe

Asphalt coated corrugated metal pipe.

Vitrified clay pipe or extra strength vitrified clay pipe.

Plain cement concrete pipe or extra strength plain cement concrete pipe.

The kind of pipe to be used for any culvert is shown on the Drawings. The best kind for a particular culvert depends on many things, such as the cost, the pressure on the pipe from the soil, the danger of being eaten away by acid in the water flowing through the pipe, and the danger of being worn away by sand or gravel carried by the water.

The Inspector must make sure that the kind and size of the pipe delivered to each culvert location are the same as those called for by the Special Provisions of the Proposal and the Contract Drawings. If a piece of pipe of a different kind or size is received, it cannot be used without the written permission of the Assistant District Construction Engineer.

<u>Field Inspection of Culvert Pipe</u>

5. Culvert pipe must be furnished by a producer who is on the approved list of the Department. A producer may be placed on the approved list after a Department representative has inspected his plant and found that he will be able to manufacture pipe meeting all requirements of the Specifications. He will receive a copy of a letter given to the Contractor by the District Office to show that the supplier has been approved. The records kept in the field office should include a copy of the report of the Department Laboratory showing that the pipe shipped is acceptable and can be used if in good condition.

The pipe in each shipment should be stamped or marked in some way to show that it comes from a lot which has been inspected and approved at the source. As soon as pipe is unloaded at the job, it should be inspected for any defects* that can be seen. Also, the Inspector should check the thickness of cast iron, concrete, or clay pipe with calipers, and should check the gage of corrugated pipe with a micrometer. Culvert pipe must meet all requirements of the Specifications when it is placed in the trench. Another method of checking corrugated metal pipe for correct gage is by weighing a measured length of pipe. Minimum weights per foot of length are given in the Specifications.

The gage of the galvanized metal used in making corrugated metal pipe is based on the weight of the coated metal in ounces per square foot. Gages, weights and approximate thicknesses, for field-checking purposes, are shown in Table 1.

TABLE 1 - Gage and Thickness of Galvanized Sheet

Gage No.	Weight of** Sheet	Approximate Thickness of Sheet in Inches	Tolerance (Plus or Minus) in Inches
8	112.5	0.168	0.008
10	92.5	0.138	0.007
12	72.5	0.108	0.005
14	52.5	0.078	0.004
16	42.5	0.064	0.003

** In Ounces Per Square Foot

If a piece of corrugated metal pipe has spots where the zinc coating has been damaged or burned by flame cutting or welding, the piece should not be used. If asphalt coated pipe has spots where the asphalt coating has been damaged, repairs may be made by coating each spot with asphaltic material furnished by the maker of the pipe for that purpose.

Handling Culvert Pipe

6. The Inspector should see to it that culvert pipe is handled properly. If the Contractor uses a method which may damage the pipe so that it will not meet the requirements of the Specifications, he should be warned by the Inspector.

Pipe should always be lowered, not dumped or dropped, from a truck to the ground, or from the ground surface to the bottom of a trench. It may be lowered by using any type of crane or a trench tripod with an "A" frame on one side and a single leg on the other side. When a crane is used for lowering the pipe into a trench, the pipe can be set in position in the trench most easily if a hairpin-shaped hook is inserted in one end of each piece of pipe.

Pipe should be rolled, not dragged, from one place to another. If concrete or clay pipe must be moved over rocky or stony ground, it should be rolled on planks laid on the ground so that the pipe will not be damaged. Although not required by the Specifications, it is good practice to store sections of asphalt coated pipe on planks or timbers so that dirt and small stones will not be pressed into the coating. Each section of pipe with a paved invert should be turned so that the paving is down. In hot weather, sections of asphalt coated pipe should be stored in a shady place, or covered with light colored tarpaulins, so that heat from the sun will not cause the asphalt coating to flow out of place.

Location of Culvert

7. The size, location, and grade of each pipe culvert should be exactly as shown on the Contract Drawings, unless field conditions make a change necessary. Although the Inspector does not decide on the proper location of a culvert, he

should be familiar with the following principles:

When a culvert is to carry water from a small stream through an embankment, the centerline of the culvert should usually be near the center of the stream and have the same general direction as the stream. Also, the bottom of the culvert should be at about the level of the bed of the stream. A possible reason for moving a culvert from its natural location is the presence of soft material which would have to be removed and replaced with granular material*. To find out whether the material of the stream bed is firm or soft, a steel reinforcing bar at least 6 feet long should be driven into the bed in several places.

If a change in the location of a culvert is made for any reason, natural drainage channels should be used wherever possible. Changing the course of a stream may result in a claim for damages by a property owner, either because more water flows onto the property or because some water is drained away from the property.

Before a road is built, water flowing over the ground during and after a rain or when snow melts will follow certain natural drainage channels in the ground. These channels will pass through the low points in the surface. When an embankment is built across a natural drainage channel, water from rain or melting snow will collect at the embankment unless it can flow through the embankment. For this reason, it is usually necessary to provide a culvert through an embankment at every natural drainage channel.

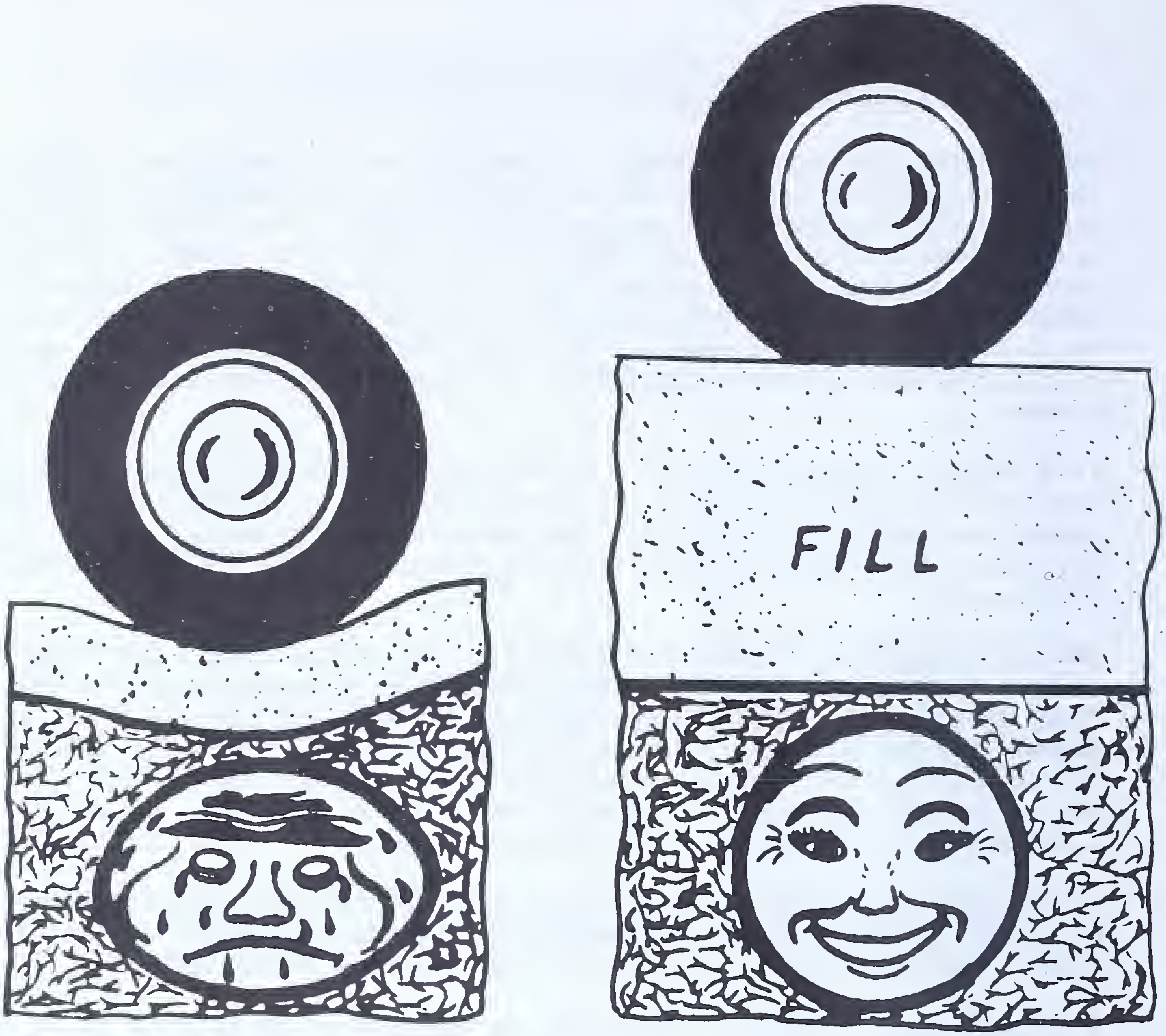
Where the ground along an embankment slopes in the same direction for a great distance, culverts should be provided through the embankment at suitable intervals. Such culverts are sometimes called drainage relief culverts.

A culvert that is not at right angles to the centerline of the road is said to be on a skew.

The line on the centerline of a pipe in the lowest part of its inside surface is called the flow line of the pipe, and the grade of a pipe is the grade of its flow line. Also, the lower part of the inner surface of a pipe is often called the invert of the pipe.

The grade of a pipe culvert preferably should be at least 1.5 percent, in order that any soil which gets into the pipe will be washed out by the flowing water. The grade should not be greater than about 6 percent, because the water would then run through the pipe at such high speed that it may carry with it gravel or fairly large stones which would wear away the invert of the pipe.

The top of a pipe culvert must be far enough below the surface of the pavement to permit the base and subbase to have the proper thicknesses and also to allow room for a cover of embankment material between the top of the pipe and the surface of the subgrade. During construction, the pipe may have to support the loads from heavy earth-moving equipment without protection from any material above the surface of the subgrade. If possible, the distance from the subgrade surface to the top of the pipe should be at least 1 foot.



<u>Outlets and Inlets of Pipe Culverts</u>

8. The outlet of a pipe culvert should be set as high as possible, in order to reduce the required amount of excavation for a ditch to carry the water away from the culvert, and to lower the cost of keeping the outlet clear. A pipe culvert should extend between 1 and 2 feet beyond the toe* of the embankment at its outlet end. The water coming out of a culvert may flow down a paved slope of the embankment or into a spillway*, or may fall onto rock. In flat country, it may be necessary to let the water from a culvert flow into an underground watercourse or, if there is no better way, into a sump.

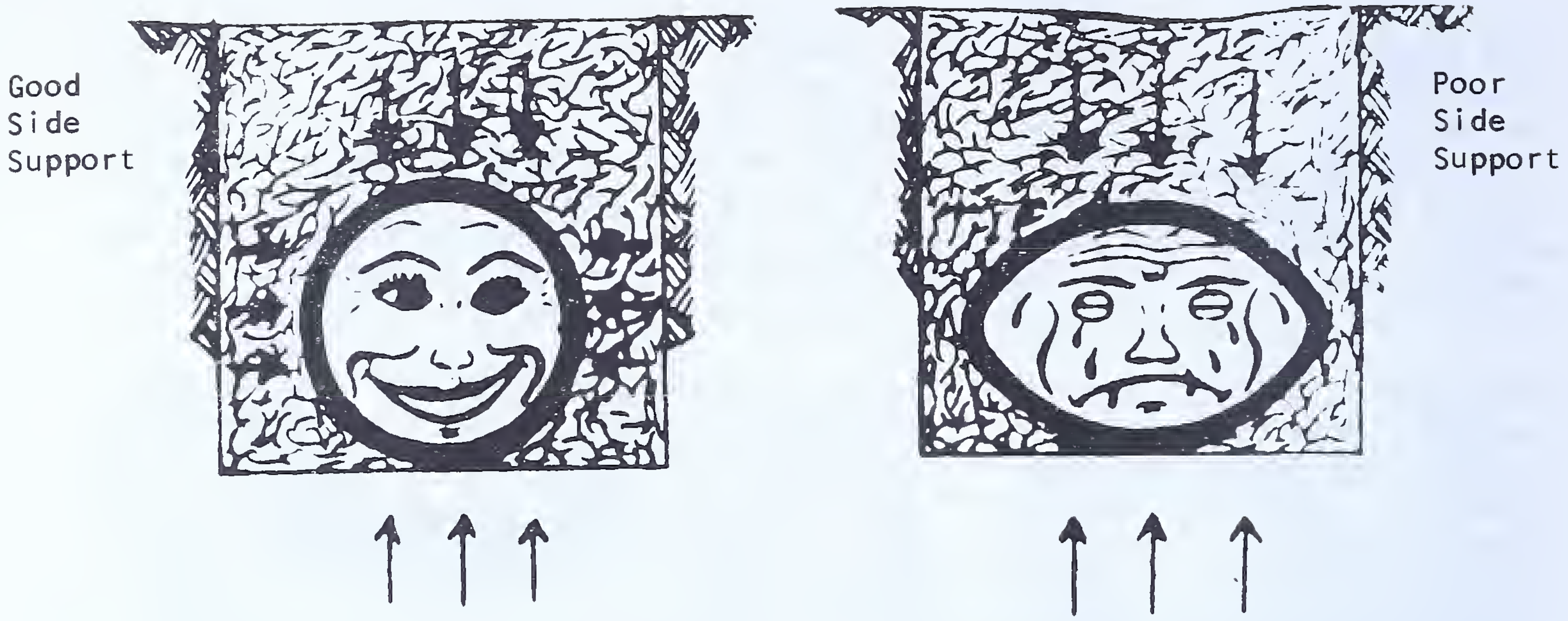
The inlet end of a pipe culvert must be placed far enough back of the edge of the roadway shoulder so that an endwall or a drop inlet can be built. When a ditch running parallel* to the roadway is needed to lead the water to a culvert, there should be a space at least 2 feet wide between the ditch and the outside edge of the shoulder. The flow line or invert of a culvert should be set low enough to carry away surface water without danger of flooding of nearby land, and to allow the water from any underdrains that are supposed to empty into the culvert to flow into the invert without danger of water backing up into the drain when the culvert is running full. However, the flow line should not be low enough to cause silting of the pipe.

Trench for Culvert Pipe

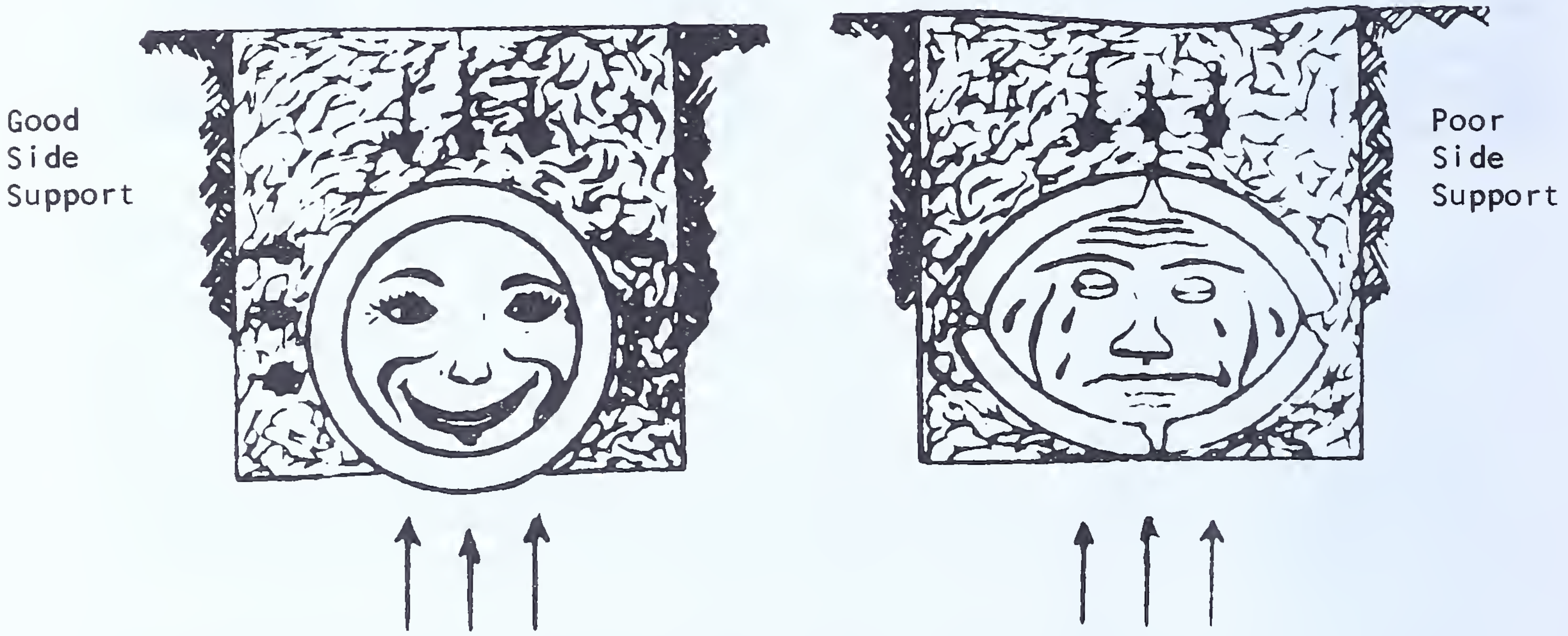
9. Every pipe culvert must be laid in a trench. Pipe must never be laid on the ground and material piled against and over them. The width of the trench cannot be less than that required by the Specifications, and the trench must be deep enough so that the top of the pipe will be at least 1 foot below the top of the trench. Where the pipe is to be placed far enough below the natural ground surface, all of the trench may be dug in the natural ground. If the top of the pipe will be above the natural ground surface, embankment material must be placed and fully compacted to a level of at least 1 foot above where the top of the pipe will be before digging of the trench is begun.

The reason for placing culvert pipe in a trench is as follows: Every pipe culvert, especially one of corrugated metal, depends on the support provided by the pressure of compacted soil against the sides of the pipe to help it carry the loads that come on its top. When a pipe is laid in a trench dug in compacted ground or embankment material, and the space in the trench on each side of the pipe is filled with compacted soil, the resistance of the pipe to crushing is greatly increased. A trench should not be wider than necessary to allow room for compacting the soil around the lower half (haunches) of the pipe, because making the trench wider increases the load on the pipe. The classification of excavation for a culvert is shown on Sheets E-5 of the Standard Drawings.

When the depth of a trench is more than about 4 feet, the sides of the trench may need to be braced in some way, especially if heavy construction equipment will be operated near the trench or if material thrown out of the trench is piled up on one side of it. A man can easily be killed if one side of a trench slides or caves in while he is in the trench. The Inspector should see to it that the Contractor complies with the safety regulations of the Pennsylvania Department of Labor and Industry in regard to bracing of trenches.



CORRUGATED METAL PIPE



CONCRETE PIPE

Use of Temporary Pipe

10. Before an embankment is built across a natural drainage channel, a temporary pipe must be put in place to permit water to pass through the embankment until the permanent culvert is installed. This temporary pipe can usually be much smaller than the permanent pipe. It should be laid parallel to the permanent pipe and with its flow line at the same level as, or a few inches below, the flow line of the permanent pipe. Also, it should be located far enough to one side of the position to be occupied by the permanent pipe to permit this pipe to be laid without trouble.

Staking Out Pipe Culvert

11. Before the construction of the embankment at a culvert is started, the Inspector should discuss the type, size, location, and grade of the culvert with the Assistant District Construction Engineer and get his approval of all details. Also, reference stakes for locating the culvert must be set on the ground by the survey corps or by the Inspector-in-Charge.

A good procedure for staking out a pipe culvert is as follows: First, stakes are set along the centerline of the roadway at intervals of 25 to 50 feet for 200 feet on each side of the proposed location of the pipe. From each of these centerline stakes, the distance from the centerline of the roadway to the planned outer edge of the shoulder is measured in each direction at right angles to the roadway, and long stakes are set along these shoulder lines. Stringlines are then run from stake to stake on each side of the roadway. Then a mark is made on each stake either at the elevation of the flow line or at a certain uniform distance above or below the flow line elevation. The stringlines are made to pass through these marks, are pulled tight, and are secured in place on the stakes. If the stringlines are not at the elevation of the flow line, the distance above or below the flow line must be shown on the stakes.

When the embankment is not more than about 2½ feet high at the outlet end of the pipe, each end of the pipe will usually be 1 foot outside the stringline at the edge of the shoulder. The 1 foot is allowed for the thickness of an endwall. If an inlet structure extends into the shoulder, the pipe need only pass through the near wall of this structure.

When the embankment is shallow at the inlet end of the pipe but more then 2½ feet deep at the outlet end, the inlet end is located as above. The right angle distance from the stringline at the shoulder edge to the outlet end of the pipe is computed as follows: Where no endwall is used, the difference in elevation between the shoulder edge and the flowline at the outlet end of the pipe is multiplied by the rate of slope of the embankment, and the result is increased by about 2 feet to take care of sloughage. If an endwall is to be constructed, the difference in elevation between the edge of shoulder and the top of pipe at the outlet end, is multiplied by the rate of slope of the embankment and 1 foot is added to the result to provide for the endwall.

When both ends of the pipe are more than $2\frac{1}{2}$ feet below the top of the embankment, the distance from the stringline at the shoulder edge to each end of the pipe is computed as just explained for the outlet end.

The above procedures apply whether the pipe is located at right angles to the centerline of the road or on a skew.* If the pipe is on a skew the distance from the shoulder edge to each end of the pipe is computed by using the elevation of the shoulder edge at the same station as the end of the pipe.

Use of Batter Boards For Pipe Culvert (See V-16B)

12. Where the trench for a pipe culvert is short, batter boards need be set only at its ends. If the trench is quite long, batter boards should be set about 25 feet apart to cover its entire length. The trench should be dug nearly to its full depth before the batter boards are set. The batter boards should be so placed that each board is about at the same distance above the final elevation of the flow line of the pipe and is higher than the top of the pipe when it is in its final position so that it will not interfere with the laying of the pipe.

To set a batter board, a stake is driven firmly into the ground on each side of the trench. The batter board is now held across the trench so it is about level and is nailed to the stakes. A surveying instrument is used to locate the centerline of the trench on each batter board. A target board is then nailed to each batter board so that one edge is at the centerline and is exactly vertical as shown by a plumb bob. A nail is driven into this edge of the target board at a predetermined distance above the flow line of the pipe. A stringline can then be stretched tightly between the nails for use in grading the ditch and laying the pipe to line and grade.

Another method of setting batter boards is to drive metal stakes on 25-foot spacing on both sides of the trench. Each batter board can be clamped to opposite stakes with the top edge at a definite distance above the flow line of the pipe, and a nail can be driven into the board at the centerline of the trench to hold a stringline.

The workman who is fine grading the trench should be given a grade stick. This stick should have a nail driven into it at a distance from its lower end equal to the distance from the stringline to the flow line of the pipe plus the thickness of the pipe shell . The point in the bottom of the trench directly under the stringline, which is at the centerline of the trench, should be brought to the proper grade by measuring vertically downward from the line with the grade stick. Grading should start at the outlet end of the trench, in order that any water in the trench will drain out.

Shaping Trench Bottom

13. A pipe culvert must be properly bedded on a firm foundation. It is not good enough to have the bottom of the trench smooth and flat and on the proper grade. As shown in the pictures for different suitable classes of bedding, the bottom of the trench for some distance on each side of the pipe centerline must be shaped to fit the curve of the pipe. Also, when bell-and-spigot pipe is used, holes must be dug so that the bells do not touch the trench bottom.

The pipe must be supported uniformly. To be satisfactory, the trench bottom must have no hard places or soft places. The best material on which to lay pipe is sand or fine soil that has been well compacted.

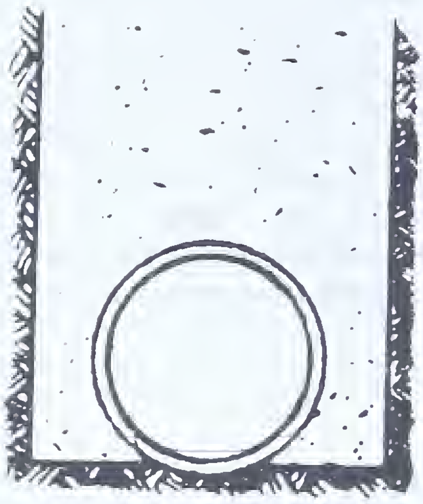
Small pockets of unstable material in the bottom of the trench should be removed and replaced with good material. If the natural material in the bottom of the trench will provide good support for the pipe, either ordinary bedding or first-class bedding can be used. Corrugated metal pipe should usually be bedded for 25 percent of its outside surface. If the material at the bottom of the trench is very soft, the pipe may have to be bedded in a concrete cradle. Where there is rock at the bottom of the trench, a suitable bed for the pipe must be provided by removing the rock from below the pipe and replacing it with a cushion of granular material* which is well compacted. If there are many large stones at the bottom of the trench, the Contractor may prefer to make the trench deeper and refill the lower part with fine material that can be easily brought to grade.

Camber of Culvert Pipe

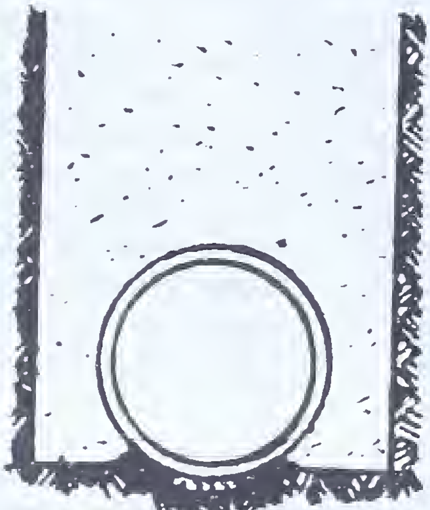
14. When a pipe culvert is placed in a high embankment, the load on the top of the culvert is much greater between the roadway shoulders than near the ends of the pipe. If the pipe were laid on a straight grade, there would be a tendency for it to settle more in the central part, as shown in the picture, and its capacity for carrying water would be greatly reduced. To allow for unequal settlement, the pipe should be laid originally so that its flow line is 1 to 3 inches above the straightline grade at the centerline of the roadway, and the height above the straightline grade should be gradually reduced to zero at each end of the pipe. This raising of the pipe is called cambering.

An easy way of providing camber in a pipe is as follows: After the batter boards and target boards have been set, marks on the target boards are first made at a uniform distance above the straightline grade. Then, a stringline is stretched tightly between nails driven in the end target boards at the marks, and the center of the line is lifted to give the desired camber. Nails are driven at stringline grade in all target boards between the end target boards, stringlines are stretched between the nails, and the grade stick is used for measuring the proper uniform distance from the stringline to the bottom of the trench.

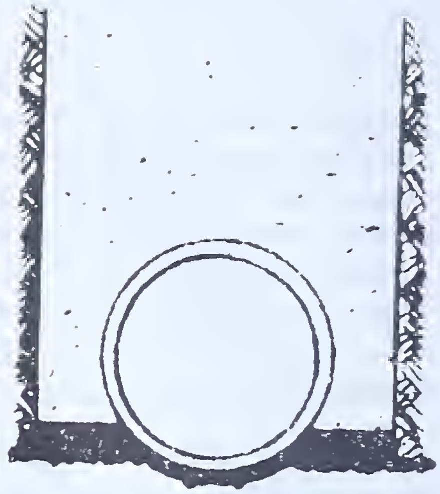
BEDDING FOR CULVERT PIPE



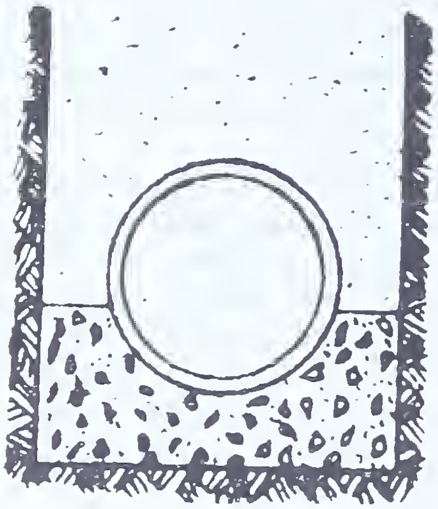
1. Ordinary Bedding



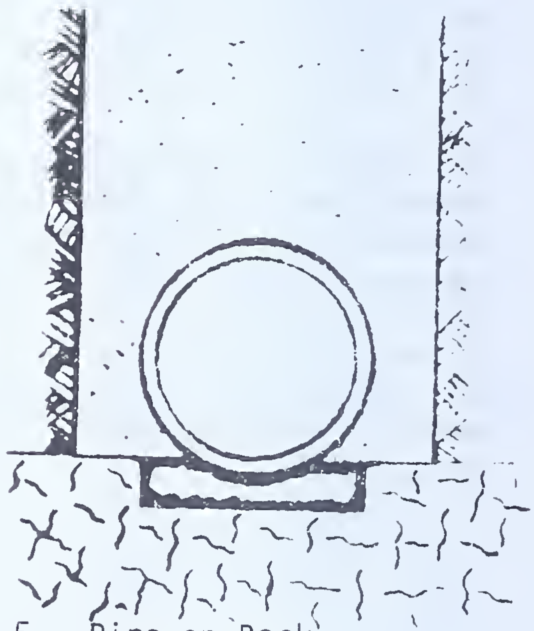
2. First Class Bedding



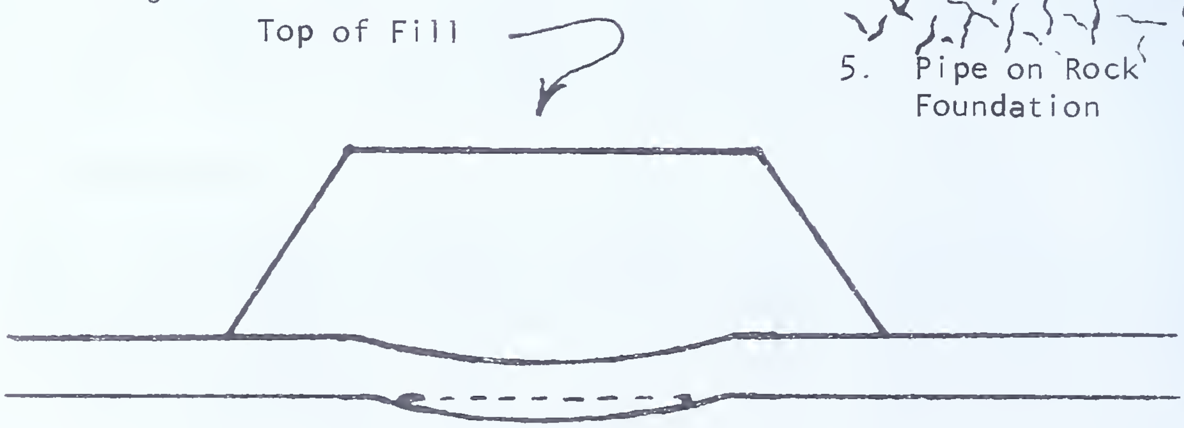
3. Pipe Bedded 25% of Surface



4. Concrete Cradle Bedding



5. Pipe on Rock Foundation



Unequal Settlement of Culvert Pipe

Construction of Concrete Cradle

15. There are two good ways of placing the concrete in a cradle under a pipe culvert after the trench has been dug to the level of the bottom of the cradle. In one method, the pipe is set to its final line and grade before the concrete for the cradle is poured into the trench. The pipe may be supported in position on blocks of wood or precast concrete laid on the trench bottom; or stakes may be driven into the trench bottom near the sides of the trench, and 2 x 4 boards nailed to the stakes with their tops at the level of the bottom of the pipe.

When the pipe is put in position before the concrete for the cradle is placed, the concrete must be very wet because it must be compacted under the pipe by spading and rodding. The cradle should extend above the bottom of the pipe for a height equal to one-fourth of the outside diameter of the pipe. In order that the pipe will not be forced out of position while the cradle is being case, the concrete must be poured carefully on both sides of the pipe at the same time. If too much concrete is poured in one place, the pipe will float. Since corrugated metal pipe floats very easily, such pipe should be tied down before the concrete is poured.

The other method of providing a concrete cradle under a pipe is as follows: The part of the cradle below the lowest point on the pipe is made of dry concrete. This concrete is placed before the pipe is put in the trench, and the surface of the concrete is brought accurately to the grade for the bottom of the pipe. If bell-and-spigot pipe is used, the concrete surface should be at the grade of the line through the bottoms of the bells. After the concrete below the pipe has become hard enough to be worked on, the pipe should be laid in its correct position on this concrete. Looped wires may be placed in the concrete before it hardens and later used to tie the pipe in position. Then wet concrete is used to complete the cradle.

Laying Culvert Pipe

16. When culvert pipe is to be placed in the trench, it should be lowered in some proper way. Cement concrete pipe or vitrified clay pipe can be easily damaged if it is dropped. If corrugated metal pipe is dropped, dents may be made in some of the ridges, or some of the zinc spelter used for galvanizing the steel or some of the asphalt coating may be knocked off. When the protective coating is damaged, the steel in the pipe will rust very quickly. If asphalt coating is knocked off a small area, the bare metal at that place must be painted with asphalt furnished for the purpose by the manufacturer of the pipe. The manufacturer's directions for applying the asphalt must be followed.

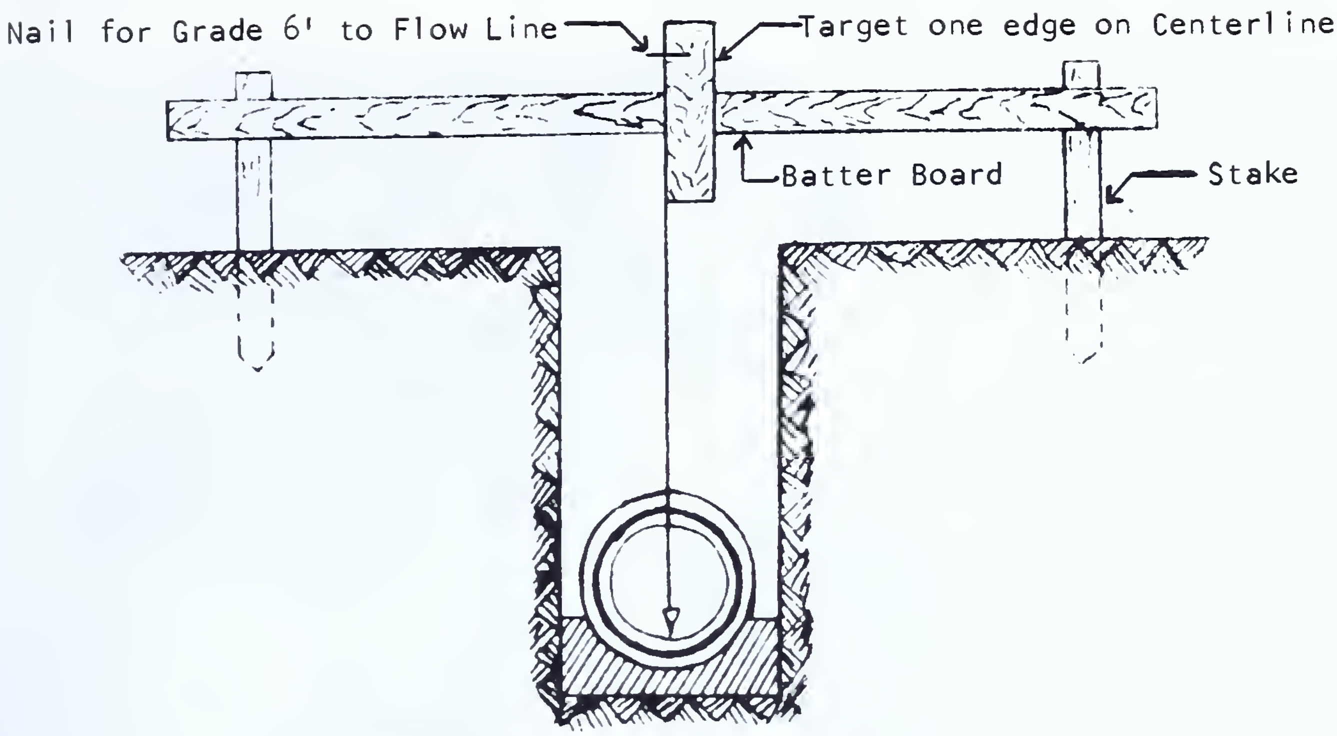
If the pipe is not heavy and the trench is narrow, a rope may be passed through the pipe and it may be lowered slowly by two men who straddle the trench and pay out the rope. A crane should be used for lowering large pipe. Each piece of pipe may be supported by a hairpin-shaped hook inserted in one end, or it may have lifting holes, or eyes, for connecting a crane hook to it.

Before a piece of bell-and-spigot pipe is lowered into the trench, it should be turned so that any small defects are at the top. Paved pipe should be laid with the paving material at the bottom. If reinforced cement concrete pipe is oval in shape, a mark labeled "top" must be uppermost. Corrugated metal pipe should be turned so that the lengthwise lap is at one side. This lap should never be at the top or bottom.

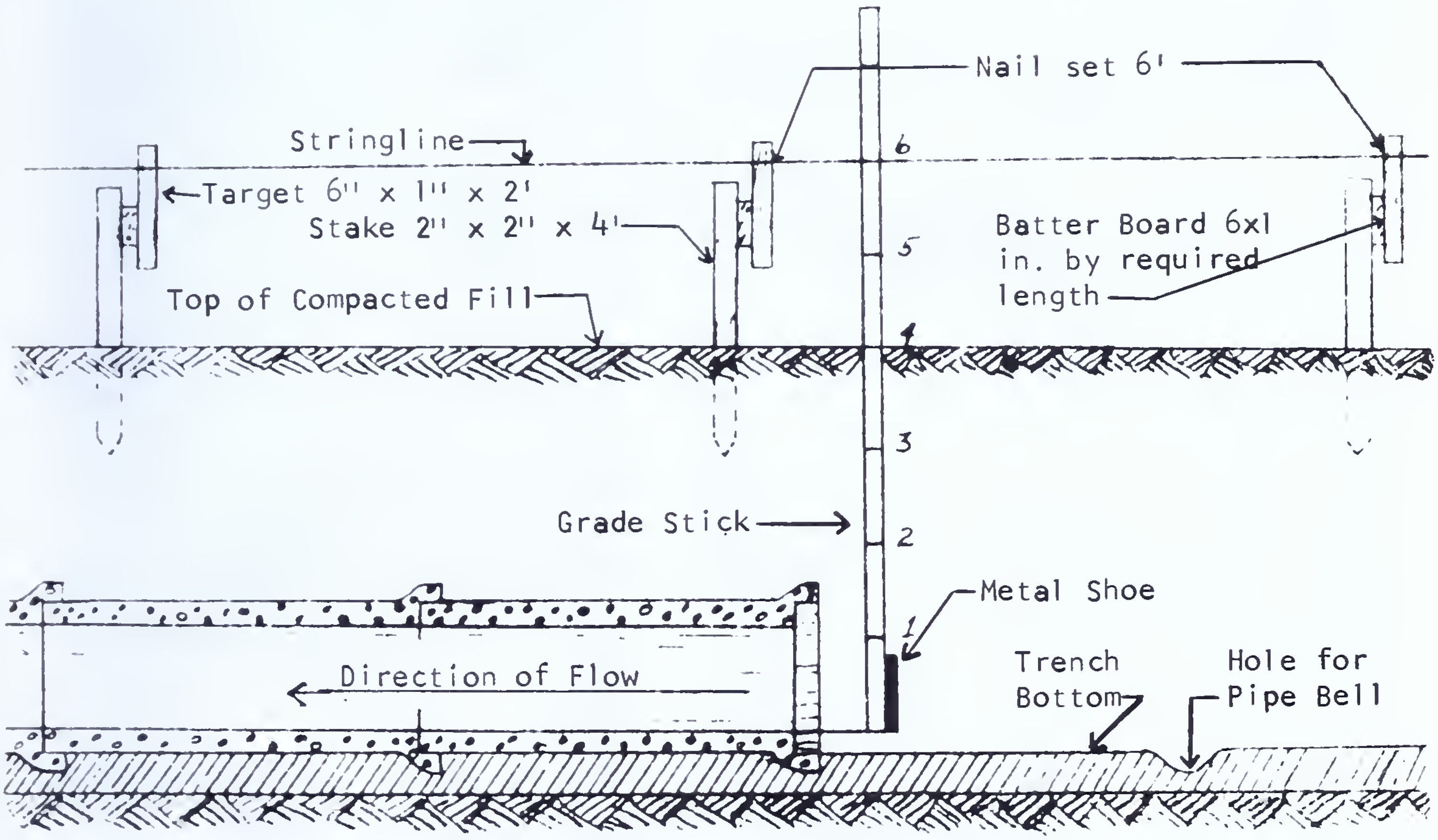
Pipe laying should be started at the outlet end of the trench. Corrugated metal pipe should be laid with the inside laps pointing downstream. Such laps are joints formed in the pipe when pieces are connected at the manufacturing plant. Bell-and-spigot pipe must be bedded with the bell end upstream. First, a small hole must be dug in the bottom of the trench directly beneath the bell to free it from the bottom in order that the weight of the pipe will be on the barrel. The inside of the bell of the piece of pipe last laid should be cleaned with a wet brush, and the lower half of this surface should be covered with freshly mixed 1:2 cement mortar. The mortar should be as wet as possible and still not sag. The entire spigot end of the piece of pipe to be laid next should be cleaned with a wet brush and forced inside the bell so that mortar is squeezed out of the joint. The position of the centerline of the pipe must then be checked with a plumb bob, and the grade of the flow line must be tested with a grade stick. A metal shoe on the bottom of the grade stick will extend into the pipe. If the pipe is a little off line, it may be straightened. If the flow line is not at the proper grade, however, the piece of pipe being set must be taken out of the bell, and the bed brought to the correct grade and shape. Fresh mortar must be put in the bell before the pipe is reset.

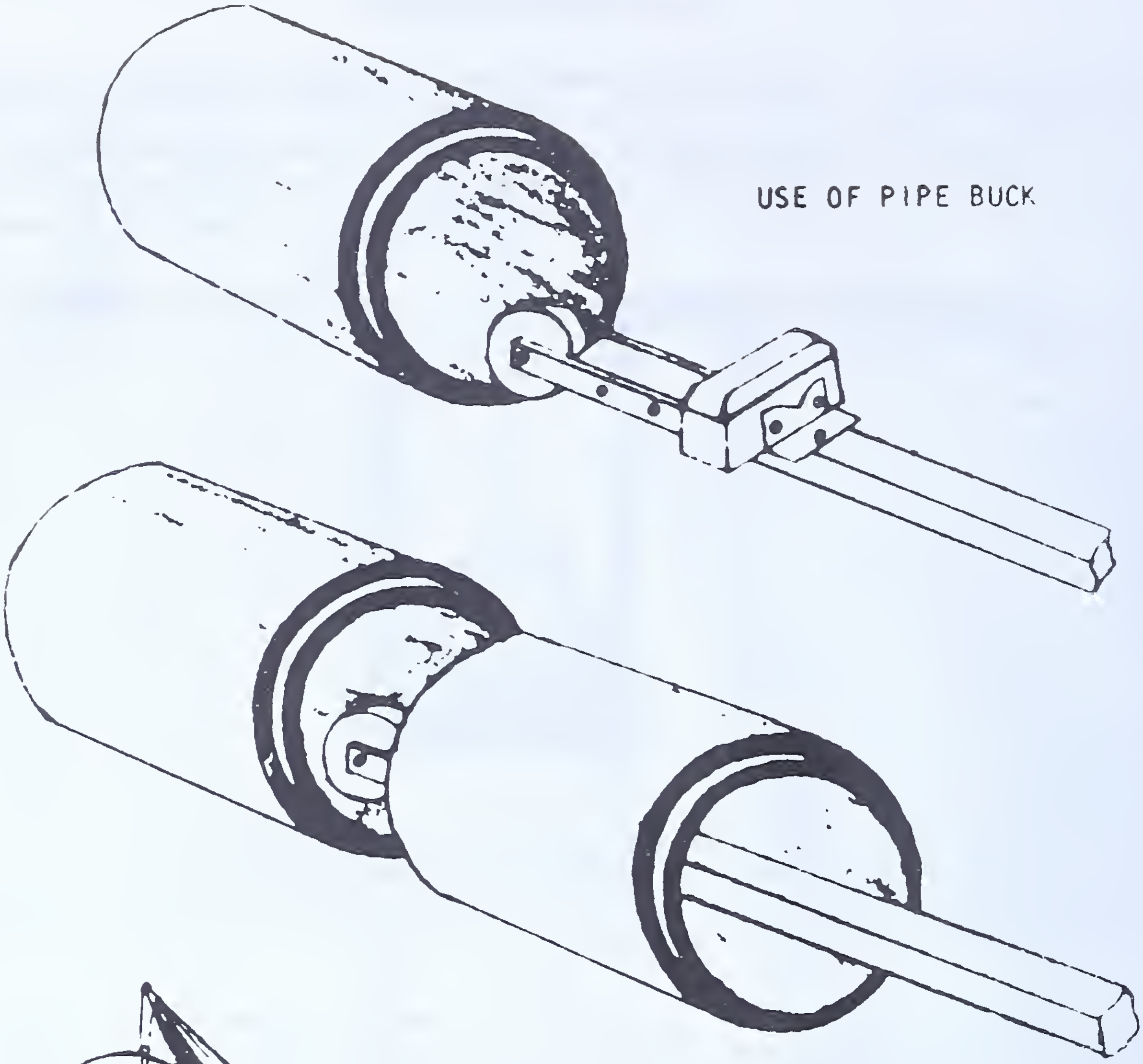
To make strong joints in the bell-and-spigot pipe, each spigot must be forced as close as possible to the inside of the bell of the piece previously laid. In small pipe, with either bell-and-spigot joints or tongue-and-groove joints, a good joint can be made by hand if a pipe buck is used. A pipe buck resembles a wheelbarrow. A small wheel at one end of the buck runs on the bottom of the piece of pipe laid. The weight of the piece of pipe being laid is carried by the saddle on the buck when its handle is lifted up. The pipe can be pushed tightly into place with little force. Large pipe usually has tongue-and-groove joints. To get a tight joint in large pipe, the pieces of pipe must be pulled together with a hand winch in the following way: A piece of timber a little longer than the inside of the pipe is jammed, in a slanting position, into a piece of pipe already laid as shown in the picture. The hand winch is anchored to the bottom end of this timber by a cable, and a rope or cable leading from the winch is fastened to a timber placed across the end of the pipe being laid. By use of the winch, the new piece of pipe is pulled tightly into position.

USE OF BATTER BOARD

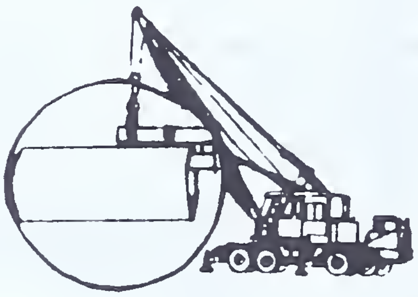


CHECKING GRADE WITH GRADE STICK

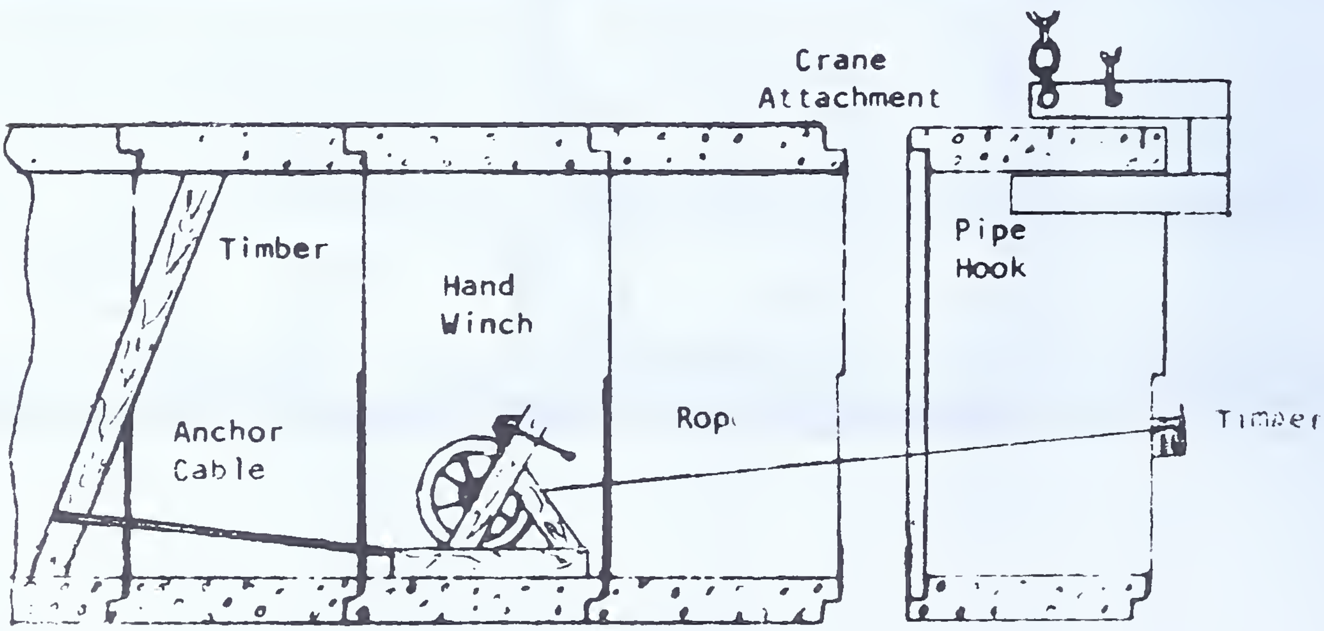




USE OF PIPE BUCK



USE OF CRANE
AND PIPE HOOK



USE OF HAND WINCH

Underdrain

Batterboards

Placing Backfill

Finishing Joints in Pipe Culvert

17. The inside of a pipe culvert must be smooth and even at each joint. Any space left between the pieces of pipe at a joint should be filled with mortar, and the joint wiped flush with the surface. When the diameter of the pipe is small, this work can be done with a burlap swab on the end of a pole long enough to reach back to the joint.

The outside part of either a tongue-and-groove joint or a bell-and-spigot joint must be filled with mortar that is trowelled to form a smooth bead. On bell-and-spigot pipe, the exposed surface of a bead should have the same shape as the corresponding part of the other side of the bell.

Beading should be done four or five pipe lengths behind the joint being made in order that the beads will not be knocked loose. The outside of the pipe next to the joint should be cleaned all the way around with a wet brush before the joint is filled and the bead made. If the bead sags at the bottom, fine soil may be packed under it to provide temporary support until it hardens. The beads must be cured in the usual way.

Lifting holes in pipe should be plugged with wooden plugs and covered with mortar at the time the beads are made. This mortar must be cured in the same way as the beads.

Mortar For Joints in Pipe

18. Two kinds of mortar are needed for the joints in a pipe culvert. One kind, which is fairly soft, is used before the new piece of pipe is laid. The other kind, which is much stiffer, is used for filling the joint from the outside and making the bead. This mortar must be stiff enough to permit the bead to be made all the way around the pipe without having the part at the bottom sag away from the pipe. Mortar should be freshly mixed in small batches. If mortar is allowed to stand more than about 30 minutes and starts to set, it should be thrown away. Old mortar must never be softened by mixing in more water, as it will not have full strength when it hardens.

Like any other portland-cement mixture, the mortar used in joints in pipe must be cured properly. If it is allowed to dry out too quickly, it will not be strong enough after it hardens. As soon as the bead has been formed around the joint, the joint should be covered with a strip of wet burlap which is folded to make several thicknesses, which should be kept wet for 48 hours.

A mortar joint must never be made under water. Also, running water must be kept away from a freshly made joint for at least 24 hours. Sometimes a trench can be kept fairly dry by letting the water flow along the sides of the trench to sumps from which it can be pumped. When there is a lot of water, the trench can be made deeper and the lower part can be refilled with about 2 feet of gravel and a covering layer of bedding material. Pumping from temporary wellpoints* in the gravel will keep the water down.

Field Joints in Corrugated Metal Pipe

19. When corrugated metal pipe is used for a culvert, the shipping lengths or units must be joined in place by connecting bands of corrugated metal.

To join two units of corrugated metal pipe with a standard band, the opened band is first slipped over the end of the unit of pipe already laid. The end of the next unit is then set about 3/4 inch from the pipe in place, and the band is tightened. The ridges and furrows of the band must match those of the two units of pipe. A plain galvanized band should be tapped with a mallet or hammer while the bolts are being tightened, in order to get the slack out of it and make a close fit. A tight joint cannot be made on large pipe by just tapping the band and tightening the bolts. A chain or cable should be put around the band and cinched up* so that the band will be tight. When corrugated metal pipe has been coated with asphalt, fuel oil may be put on the end of each unit of pipe so that the band can slip around the pipe while it is being made tight. This oiling is usually most necessary in cold weather.

Elongating Corrugated Metal Pipe

20. When corrugated metal pipe is to be used under a high embankment, it must be elongated vertically (made taller than it is wide) in accordance with the Specifications. This stretching is something like putting camber in the falsework for a bridge.

Specifications require that asphalt coated pipe and pipe with a paved bottom be elongated at the factory before it is shipped to the job. Corrugated metal pipe without a paved bottom may be elongated at the factory or in the field.

Other Features in Laying Pipe

21. At the end of each day, the trench with no pipe in it should be blocked off by a temporary dam or tight bulkhead located a short distance beyond the end of the pipe. The end of the pipe should not be blocked, because water filling the trench would then float the pipe and break the joints. Backfill should be compacted around and over corrugated metal pipe as soon as it has been laid, because this type of pipe floats easily and floating will bend and kink the pipe. In case a piece of pipe floats, it must be pulled out. If it has been damaged, it must be rejected.

When a pipe culvert must have a definite length, as between endwalls, and a short piece must be used to obtain the required length, a full length piece should be put at each end of the culvert and the short piece should be the second or third piece from one end.

Inspection of Pipe in Place

22. All pipe must be inspected in place before backfilling is started. Each mortar joint of large pipe should be inspected from inside the pipe to make sure that it is filled. Even if the pipe is fairly small, the joints can be checked from the inside by a man riding on a crawler, like that used by an auto mechanic to get under a car. The crawler is pulled through the pipe with a rope.

The bead on the outside of each mortar joint should also be checked after the entire culvert has been laid. Any weak or cracked mortar should be chipped out and replaced. Any piece of pipe that has been dented, cracked, or broken will have to be taken out and replaced, unless repairs that are satisfactory to the Assistant District Construction Engineer can be made without removing the piece.

Placing Backfill in Trench (See V-16C)

23. Making sure that the Contractor does a good job when compacting backfill around a pipe culvert is one of the hardest jobs of an Inspector. Proper compaction of the backfill is very important for two reasons. One is that well compacted material under the lower half, or haunches*, of the pipe and between the pipe and the walls of the trench helps to keep the pipe from being crushed by the loads on its upper part. Also, poor compacted backfill will always settle, and there will be a low spot in the road above it.

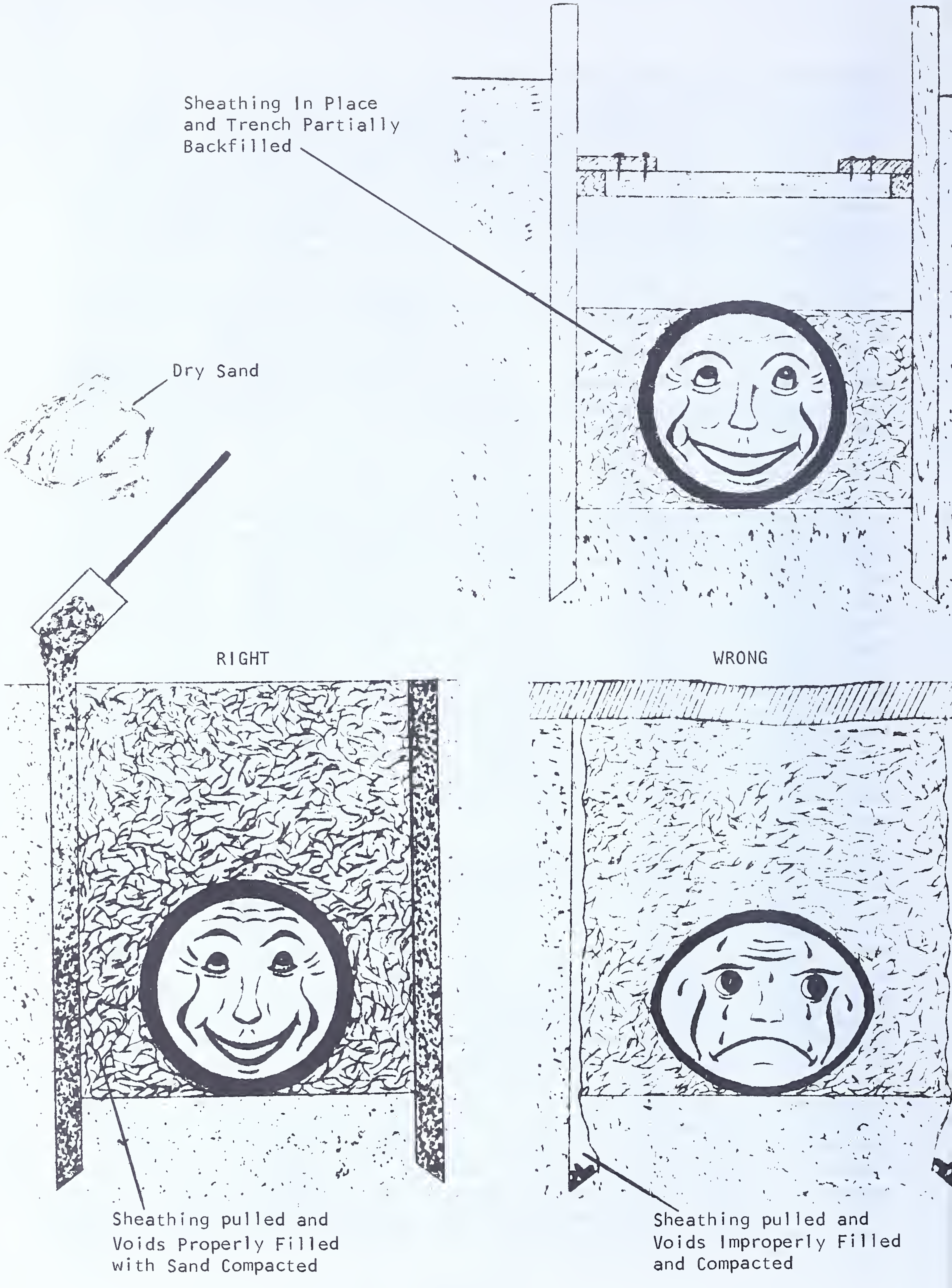
Before any pipe is laid in a trench, the Inspector-in-Charge should have a clear understanding with the Contractor in regard to the methods, materials, and equipment that are to be used in the backfilling operations. Any disagreements should be referred to the Assistant District Construction Engineer. When all the details have been approved, the Inspector-in-Charge must see to it that each of his Inspectors knows how the job is to be done and that the Contractor has given his foremen and workmen the proper instructions.

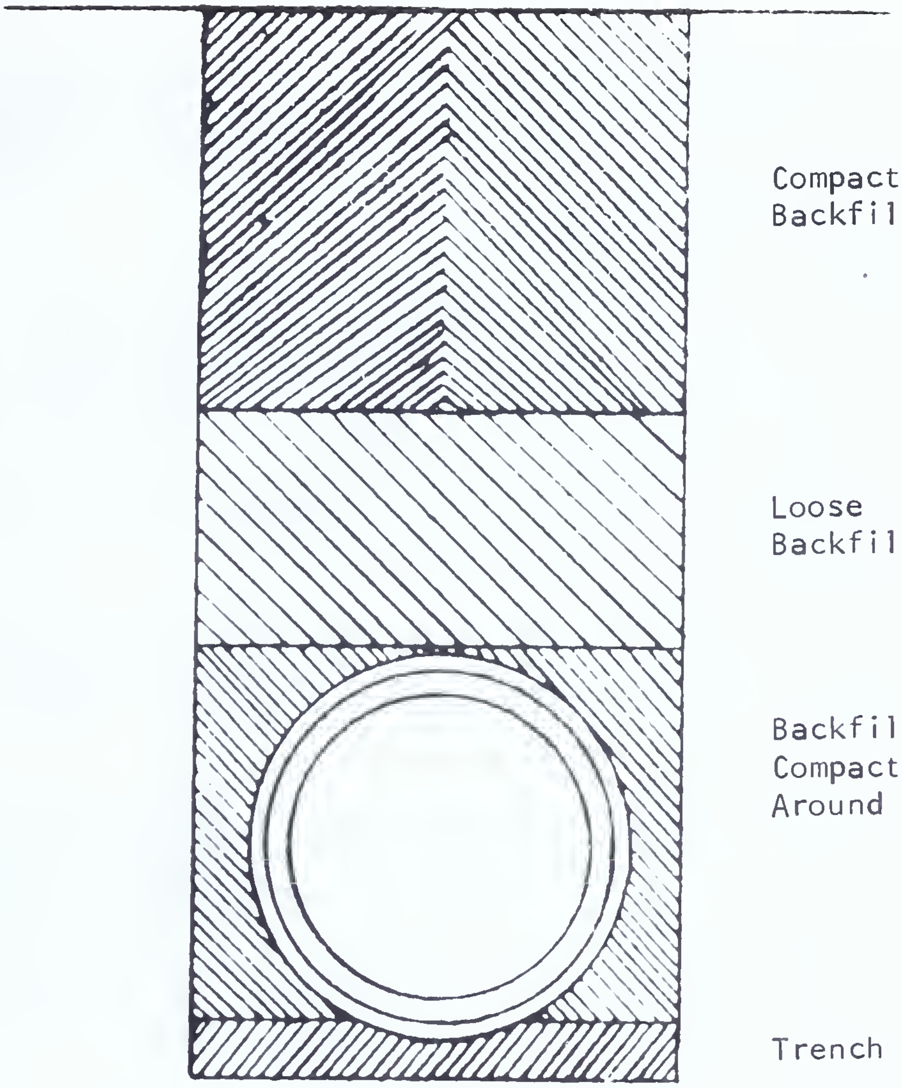
Backfill material must never be bulldozed or dumped into the trench. It must be shoveled into the trench from a spoil bank* or from piles located at least 3 feet from the edge of the trench. Large lumps or large stones must be removed from material that is thrown into the trench around the pipe. The backfill must be brought up slowly and evenly on both sides of the pipe. It is most practical to compact the backfill as it is being placed, instead of placing the material in definite layers and compacting each layer, but if the backfill is placed in layers or lifts, the depth of a lift must not be more than 4 inches.

Most of the work for compacting the material under the haunches* of the pipe must be done with hand tools, since mechanical tampers will not usually reach this space. Hand tampers or short pieces of timber may be used. One man shoveling to two men tamping is about right for this work. The backfill between the pipe and the sides of the trench and around the upper half of the pipe should be compacted with power tampers. There should not be more than two shovelers for each power tamper.

The soil used for backfill should be moist enough to pack well. If the soil is too dry, water must be added by sprinkling it on the spoil bank* and mixing it in before the soil is thrown into the trench. A rough test can be made by squeezing the soil in the hand. It should make a firm cast which will not break up when handled or tossed in the air. Fully compacted material will usually "ring" under the blows of a power tamper. If deep dents remain in the soil after it has been tamped, the soil is probably too wet. Dry soil should then be mixed with the material in the spoil bank. Bracing and sheeting must be raised or removed as the trench is filled, but enough must always be left in place to keep the trench safe.

If uprights are left in place until after backfilling, the spaces left when they are pulled should be filled with dry sand. The sand should be pushed and compacted, with a piece of board, into the hole left by removing the uprights or sheeting. In most cases, the backfill in the trench and embankment material over the trench should be compacted up to subgrade level. However, when the culvert is to be covered with a high fill, the Specifications require that a special method, called the imperfect trench method, be used to protect the pipe from the weight of the fill.


Sheathing In Place
and Trench Partially
Backfilled
Dry Sand
RIGHT
WRONG
Sheathing pulled and
Voids Properly Filled
with Sand Compacted
Sheathing pulled and
Voids Improperly Filled
and Compacted



In such a case, after the backfill has been compacted up to the level of the top of the pipe, a cushion of loose soil is placed over the pipe for the whole width of the trench. The thickness of this cushion must be at least equal to the diameter of the pipe but not less than 3 feet. The material for the cushion should be shoveled into the trench from both sides, so that it will have nearly uniform density*. After the cushion has been brought up evenly to the required level, the rest of the material in the trench or in the embankment over the trench must be fully compacted. When the backfill is placed in this way, the compacted material over the cushion carries the load from the fill above it to the sides of the trench by arch action, like that in an arch bridge of masonry. This arch action takes a great deal of the load off the pipe and helps prevent the pipe from being crushed. Also, if the backfill above the cushion is fully compacted, especially next to the sides of the trench, there will be no settlement of the road, because the "plug" of compacted material will key into the sides of the trench.

Special care must be taken in placing backfill material around elongated corrugated metal pipe. Selected material must be used up to a level of at least 12 inches above the middle of the height of the pipe. This backfill should be placed in uniform lifts not more than 4 inches deep. It must be firmly tamped under the pipe and along both sides. If the haunches of the

pipe are not supported properly, the vertical diameter of the pipe will be short when the embankment is completed. The rest of the backfill may be placed as described for culvert pipe that has not been elongated.

Inspection of Elongated Pipe

24. From the time the depth of the fill above the top of an elongated pipe exceeds 5 feet, until the fill is completed and thoroughly compacted, the pipe should be examined each day. If there is no indication that the top cap or bottom sill in the pipe is about to bend, or that the ridges in the pipe are being crushed, the struts are usually left in place until the project is completed. Whenever any sign of such bending or crushing is noticed, the wedges at the ends of the struts should be loosened. If necessary, the struts should be removed.

A pipe is sometimes elongated at the factory by the use of ties placed across the pipe. Tied pipe must be watched carefully while the backfill is being placed. If there is any sign that the ties are denting or damaging the pipe, the ties should be cut.

If there has been no sign of trouble with elongated pipe, and the struts or ties do not interfere too much with the flow of water, the struts or ties should be left in the culvert until the embankment has been completed and has had time to settle. However, struts and ties must be removed at the end of construction. If left in place, they will hold back trash that is washed into the culvert by heavy rains and will block it. Thr removal of struts and ties should always be checked during final inspection.

After the project has been completed, and struts and ties have been removed from a pipe that has been elongated, the vertical diameter of the inside of the pipe (including the thickness of any paving) should not be less than the nominal diameter by more than 1 percent. Also, the vertical diameter of the inside of any piece 20 feet long should not vary more than 2 inches.

Inspector's Check List for Pipe Culverts

25. During construction of a pipe culvert, the Inspector should see to it that the following conditions exist.

1) The pipe came from an approved source and has been tested.

2) The pipe is unloaded, stored, and moved in such a way that it will not be damaged.

3) Pipe that does not meet the requirements of the Specifications in the field inspection is shipped back to the manufacturer or taken off the job.

4) The culvert is located so as to best meet field conditions, and the pipe is long enough.

5) The trench is excavated to the required depth in natural ground or in fully compacted embankment.

6) The bottom of the trench is at the right grade, and proper allowance has been made for camber.

7) The trench is excavated to the right width.

8) The material at the bottom of the trench will provide uniform and stable support for the pipe.

9) The bottom of the trench is shaped to fit the pipe, and holes have been dug for bells (when bell-and-spigot pipe is used).

10) The trench is braced safely.

11) The pipe is laid with tight joints, and mortar joints are cured properly.

12) The backfill material is free from large stones or lumps, and has the right moisture content for good compaction.

13) The backfill is placed slowly and evenly, and the material under the haunches of the pipe and between the pipe and the sides of the trench is fully compacted.

14) The pipe is protected against heavy construction loads.

<u>Combination Storm Sewer and Underdrain</u>

26. A combination storm sewer and underdrain serves both as a part of the surface drainage system for a road and as a part of the subsurface drainage system. Serving as a storm sewer, it carries away surface water which enters it from inlets built for that purpose. Serving as an underdrain, it carries away underground water that flows into it directly, and it also collects water discharged into it from drains placed in the subgrade or the subbase.

A pipe is always used for a combination storm sewer and underdrain. The possible kinds of pipes are as follows:

Perforated corrugated metal pipe
Perforated asphalt coated corrugated metal pipe
Reinforced cement concrete pipe
Vitrified clay lined reinforced cement concrete pipe
Extra strength plain cement concrete pipe
Extra strength vitrified clay pipe

Cement concrete pipe or vitrified clay pipe must be of the bell-and-spigot style. All pipe must be laid in a trench, the width of which should not be more than 1 foot greater than the outside diameter of the pipe at a joint.

The bottom of the trench should be prepared as explained for a pipe culvert. Perforated metal pipe is laid with the holes up**. Part of the upper section of each joint in concrete or clay pipe is left open, while the rest of the

** This is true for storm sewers only.

joint is sealed with mortar. The part of the trench below the middle of the height of the pipe should be backfilled with impervious* soil taken from excavation for the project. This soil must be fully compacted under the haunches* of the pipe, and its surface should slope slightly upward from the pipe to the sides of the trench.

Subsurface Drainage

27. According to the general principle that dry soil is strong and wet soil is weak and will cause trouble, underdrains and subdrains are put in to make sure that the subgrade does not get soaked with water. Underdrains running parallel to the centerline of the roadway may be needed when a subbase is used. Where there is no subbase, the Assistant District Construction Engineer usually decides during construction whether or not subsurface drainage is necessary in a certain place. If underdrains or subdrains are needed, their exact locations, types, and sizes are selected so that the subsurface drainage system will be most suitable for the field conditions in the particular case.

The Inspector-in-Charge and other Inspectors on the job must start to look for wet places where subdrains may be needed as soon as work on clearing and grubbing is begun, and must keep on looking until the project is completed. Seepages of water often show up only during the spring of the year or after heavy rains. Excess water found in the subgrade should always be traced to its source. Test pits and trenches should be dug where necessary to locate the source of a seepage.

Subgrade Drains

28. Drains are placed in the subgrade to take care of water from a spring or seepage that cannot be cut off before it gets into the subgrade, or of water that may get into the subgrade from the surface of the road. If the water comes from the road surface, subgrade drains must always be located at low points, where the water would collect. It is almost impossible to repair a subgrade drain. If one gets plugged up, it cannot be cleared. As a result, the water that should be removed by the drain soaks into the subgrade. For this reason, each subgrade drain must be designed and built so that it will not stop working.

A subgrade drain should usually consist of a trench filled with granular material. The best material for such a drain depends on the kind of soil in which it is laid. Crushed stone may be used for drains in rock, gravelly soil, or fat clay that does not soften when water stands on it. However, if crushed stone is used in soft clay or silty soil, the water that runs into the drain will carry with it fine soil particles which will soon plug the spaces between the particles of stone. In relatively fine soil, a drain made of clean concrete sand or clean sand-gravel will work satisfactorily for a long time. Actually, a certain volume of sand has almost as much space between its particles as does an equal volume of crushed stone. Since the spaces in sand are smaller, however, fine particles do not get in them to plug the sand drain. When subgrade drains are to be built through a soil that may plug the drains, the District Soils Engineer should help select the material to be used for the drains.

The material used for a subgrade drain must always be clean*, and it must be handled so that no dirt gets into it while the drain is being built. Even a small amount of mud in the material will reduce greatly the speed with which the drain will carry water away. After the drains have been built, they must be protected so that water carrying mud cannot run into them before the surrounding subgrade material is placed. If dirt gets into a drain during construction, the dirty material must be removed and replaced with clean material. A subgrade drain under a subbase should be covered with a layer of roofing paper or subgrade paper.

Unless a subgrade drain is under a superelevated roadway, or some other grade is shown on the Drawings, the bottom of the trench for the part of the drain beneath the pavement should have a slope of 1/4 inch per foot toward the shoulder. The slope of the drain from the edge of the pavement to the outlet should be 1/2 inch per foot. The outlet should be located at such an elevation that water will not flow through the drain backward. When a drain is to discharge into a ditch, the outlet of the drain should not be too near the flow line of the ditch. If the outlet is too low, the drain may carry water back under the pavement when the ditch is running full of water.

Trenches for subgrade drains may be at right angles to the centerline of the roadway or may be skewed*. Where the grade of the roadway is more than 1 percent, the trenches are usually skewed in order that the required depth of excavation will be reduced. The outlet ends of all subgrade drains must be marked with stakes and referenced on the Construction Drawings. During construction and just before final inspection, the Inspector should check the outlet ends of subgrade drains in embankments to make sure that they are open and the drains are working.

Stone Underdrains and Stone Foundation Underdrains

29. A stone underdrain consists of a trench filled with stone. The trench is made 12 inches wide at the bottom and 21 inches deep, and the sides are battered outward 1 inch in 10 inches. The procedure for filling the trench is described fully in the Specifications.

A stone foundation underdrain consists of a trench filled with gravel or crushed stone. Such an underdrain may be placed under a curb, gutter, roadway, or other structure. The trench is made 15 inches wide at the bottom and has vertical sides. It is about 15 inches deep for a Type A underdrain, and 24 inches deep for a Type B underdrain. When the drain is under a rigid base or pavement, the top of the aggregate is covered with one layer of approved building paper or tar paper.

Uses of Pipe Underdrains

30. A pipe underdrain is built by digging a trench, laying a pipe in it, and backfilling it. Type I backfill consists of coarse aggregate in the lower part of the trench and a layer of soil at the top. Type II backfill consists of layers of coarse aggregate, fine aggregate, and soil. A pipe foundation underdrain is built like a pipe underdrain, but no soil backfill is used in the upper part of the trench.

Pipe underdrains or pipe foundation underdrains are used for five general purposes:

1) To drain springs and cut off seepage in the original ground either under an embankment, or along benches where the highway is located on the side of a hill.

2) To lower the surface of ground water so that it will be below the surface of the subgrade.

3) To collect and carry away water that seeps into the subgrade through the road surface or shoulder.

4) To cut off seepage which might cause a slide.

5) To provide an outlet for water that gets into a subbase.

It is the responsibility of the Inspector-in-Charge to look for any condition which may create a drainage problem. If he notices such a condition at any time, he should notify the Assistant District Construction Engineer. Underdrains can then be provided wherever necessary to keep water from being trapped.

After the work of clearing and grubbing has been finished, but before the construction of an embankment is started, the Inspector-in-Charge must inspect the original ground for signs of springs, slides, or seepage. Also, after the benches* have been formed on a side-hill location, he must look for any signs of seepage or any layer or stratum* of impervious material*, such as fireclay or coal, which may cause seepage during wet weather. He must study ground-water conditions while grading work is in progress and after it has been completed. Whether the water gets into the subgrade from outside the roadway or through the road surface, it must be allowed to escape.

In an area in which slides have already occurred, underdrains seldom help because the ground is usually too broken and has too many openings through which surface water can flow. In order that underdrains may be effective for cutting off springs or seepage above a slide area, all loose material must be taken out before the drains are placed. The drains may have to be put in deep trenches or in horizontal holes bored in the side of a cut.

Since a subbase serves as a continuous drain under a base course or a pavement, an underdrain for carrying away water must be provided on one side or on each side of the roadway wherever the subbase is in a cut.

Construction of Pipe Underdrains

31. The pipe for a pipe underdrain or a pipe foundation underdrain may be of perforated vitrified clay, cradle-invert vitrified clay, perforated bituminized fiber, porous cement concrete, or perforated corrugated metal. Neither porous cement concrete nor perforated corrugated metal should be used where the pipe may be exposed to acid water. Vitrified clay pipe may be of the bell-and-spigot type or may have plain ends.

After the location and type of underdrain have been selected by the Assistant District Construction Engineer, layout stakes are set by the Contractor and checked by the Inspector. The Contractor must place batter boards at intervals of not more than 25 feet along the line of the drain. They are used in the manner described for pipe culverts.

Perforated vitrified clay pipe or perforated corrugated metal pipe is usually placed with the perforations down. Such pipe must be laid in a straight line and so that the groups of perforations are equally spaced from the lowest point on the centerline of the pipe in its final position. Bell-and-spigot pipe must be centered by mortaring or calking the bottom half of the joint, unless the pipe is made with lugs that will keep the pieces of pipe lined up at the joint. If the vitrified clay pipe has plain ends, approved spring-wire clips or split couplings must be used at the joints. In general, perforated corrugated pipe is preferred for shoulder and lateral drains*, because there is less danger of breakage or crushing.

Placing Backfill for Pipe Underdrain

32. Detailed instructions for placing Type I or Type II backfill in the trench for a pipe underdrain are given in the Specifications. Some other type of backfill may be required by the Special Provisions of the Proposal or authorized by the Assistant District Construction Engineer. For example, if a trench for perforated metal pipe is dug in fine-grained soil, the best filter material* may be concrete sand or sand-gravel. If a trench for bell-and-spigot vitrified clay pipe is dug in fine-grained soil, it may be best to place a filter material such as crushed stone or gravel next to the pipe and to use concrete sand between the coarse aggregate and the sides of the trench and also above the coarse aggregate. The coarse material prevents the sand from passing through the open joints in the pipe, while the sand allows water to get into the pipe but keeps out the fine particles of soil which could clog the pipe.

Care must be taken to keep dirt out of the filter material while the trench is being filled. One way of keeping the filter clean is by laying a canvas cover over the ground at the top of the trench and over the sides of the trench while the filter backfill is being put in the trench. A better way is to use a plywood or metal form that is about 10 feet long, is open at the top and bottom, and has handles for lifting it out of the trench after the backfill material has passed through it into the trench.

A form is especially useful when coarse filter material such as gravel or crushed stone is to be placed around the pipe, and sand is to be used for filling the rest of the trench. After the bottom of the trench has been shaped and brought to grade and the pipe has been set in the proper position on the bed, the form is put in place so that it rests on the pipe bedding and the pipe is centered in it. Then the coarse filter material for backfill is dumped into it to the proper level, and sand backfill is placed between the form and the sides of the trench. The form is now lifted out of the backfill and moved down the trench. Finally, sand backfill is used for the whole width of the trench to the required level, and the rest of the trench is filled with compacted soil.

The Contractor may decide to speed the placing of filter backfill by using a transit-mix truck. This method makes it easy to chute* the right amount of material directly into the trench.

It is important to prevent surface water from getting into the trench for a pipe underdrain. For this reason, the top of the trench should be sealed with a layer of impervious material, such as clay soil. Surface water not only overloads the underdrain but also tends to wash fine soil particles into the filter material. The surface water should be taken care of by surface drainage.

Other Features of Pipe Underdrains

33. Even the most carefully built underdrains are likely to become plugged in due time. Plugging is rapid right after the underdrain has been put into use, but proceeds very slowly after about a year. To permit a long underdrain to be cleaned out any time after it has been completed, Y-connections should be set in the pipe line at suitable intervals during construction. The arm of each Y should be in a vertical plane and should point toward the higher end of the drain. A passageway from the ground surface to each Y is provided by a line of pipe of the required length. The top of each such line is plugged until the underdrain is to be cleaned. Then the plugs are removed, and the underdrain is flushed out with water from a hose.

Provision must be made for allowing the water to flow out of a pipe underdrain. The outlet for an underdrain is a pipe placed in a trench which is backfilled with soil. Since the purpose of an underdrain outlet is to carry away the water from the underdrain, and not to collect more ground water, pipe without perforations must be laid with watertight joints. The pipe may be of vitrified clay, plain cement concrete, corrugated metal, or bituminized fiber. The material used should be the same as that of the pipe for the underdrain itself. The procedures for grading and shaping the trench bottom, laying the pipe, and placing backfill are described in detail in the Specifications.

Final Subdrainage Inspection and Records

34. The Inspector-in-Charge must check all the drains that have been installed on the project, far enough in advance of the start of paving to permit corrections in the drainage system to be made. He must make sure that each drain is in working order, and that no replacements are necessary because of settlement or crushing. If inspection shows that conditions at any drainage structure have changed since the structure was built, the Assistant District Construction Engineer should be notified.

It is important that the Inspector-in-Charge keep a complete record of all underdrains. Their locations, types, and sizes, with sketches that show the flow line elevations at the inlet and outlet must be included in a permanent field record book.

After the rough grading is completed, careful inspection may show the need for additional drainage. For example, top-of-fill shoulder drainage at the edge of the berm may be needed to protect parts of the berm and the side slope of the fill from being washed away by water running or draining, from the roadway. Ditches may be needed at the tops of cuts* and the toes* of embankment

where the natural ground slopes toward the cut or embankment. Additional drainage may be needed in the median* strip to prevent ponding*. To prevent washing of silty soil into drainage ditches at the side of the road, flattening the slopes of cuts and fills to a greater degree than shown on the Drawings or Cross-Section may be necessary. All such matters should be brought promptly to the attention of the Inspector-in-Charge, and the Assistant District Construction Engineer should be informed.

INSPECTION CHECK LIST FOR DRAINAGE

1) Has all available information regarding drainage adjacent to the project been obtained from local residents?

2) Have all watercourses been checked for high water flow and culvert areas compared with requirements?

3) Have all cuts been checked for springs and seepage after heavy rains?

4) Has drainage for entire project been reviewed for adequacy? Is additional drainage, such as ditches at top of cuts or toe of embankment, needed?

5) Is material planned for use in subdrains appropriate to the type of soil in which they will be placed? Has District Soils Engineer been consulted?

6) Have all matters pertaining to drainage been brought to the attention of the Inspector-in-Charge and Assistant District Construction Engineer?

7) Have adequate outlets been provided for all subdrains? Are outlets so located there is no chance of water backing up into subdrains during heavy storms?

8) Have all pipe outlets been checked to make sure they have not been crushed or displaced during construction?

9) Have all outlets been checked after periods of heavy rainfall to make sure that they are flowing freely?

10) Are all outlets shown on Drawings, and staked in field, so that they can be easily located and kept in open condition by maintenance forces?

CHAPTER VI

BASE COURSES

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CHAPTER VI

BASE COURSES

Importance of Base Courses (See VI-0A)

1. If a pavement built of a strong base* course and a surfacing of asphaltic concrete* is placed on a good subgrade* or subbase*, it will carry any normal traffic load and will last a long time. Many of the older roads in Pennsylvania were built in this way and are still giving good service under heavy traffic. To get good results uniformly, the base course, or base, must be well constructed, and have uniform strength. If there are weak places in the base because it does not have the full thickness, or because the materials are of poor quality, or are not fully compacted*, traffic will find these places and push the pavement surface down. This movement will cause a bump or a pothole. To fix it will cost money.

Types of Bases

2. Many types of bases will give good service. Any base must be built so that the pressure of a truck tire applied to a small area on the surface of the road will be spread over a much larger area of the subbase or subgrade, which can then support the truck without moving down. The conditions are like these: If a man steps directly on soft mud, his foot will sink in. However, if he lays a wide board on the mud and steps on it, the board will sink very little. The man's weight is spread out by the board. A base course acts in much the same way in spreading the weight of a truck.

Bases are of three general types. One type is the rigid base, which spreads the load by slab action. A base of portland cement concrete is an example. Another type is the crushed aggregate base, which spreads the load because the edges and corners of the pieces of aggregate lock the pieces together. The Specifications describe a Crushed Stone Base Course and several types of Crushed Aggregate Base Courses. In this Construction Manual, the general term "crushed aggregate base course" will be used to include the Crushed Stone Base Course, the Crushed Aggregate Base Course, Type A or Type B, and the lower courses of the Crushed Aggregate Base Course, Type AP. Also, the term "aggregate" will be used to mean stone or slag.

A third type of base is one in which soil particles and pieces of aggregate are held tightly together by some cementing material, such as portland cement*, lime-pozzolan*, asphalt*, or tar*. A base of this type is called a stabilized base.

Causes of Failure of Base Courses

3. The life of the surface course depends on the base; if the base fails, the surface course will fail. It is important that the base be supported uniformly by the subbase or subgrade. The purpose of the base is to spread

NOTE: Words marked with an * are explained in the Word List at the back of this book.

loads on the pavement over the subbase or subgrade. Even a rigid base cannot act as a bridge over a soft or weak spot in the subgrade. If a rigid base is built on a subgrade which has a lot of clay or silt in it, the base may break up because of pumping action of the subgrade under traffic. It is likely that water will get into the subgrade from the surface, from the shoulders, or from below. The fines* in the subgrade material will then become muddy, and the action of traffic will force some of the muddy material out from under the base slab. The slab will then start to move or rock. Subgrade material will be pumped up through joints or cracks or will be blown out from under the edges of the slab. After uniformity of support from the subgrade is lost, the weight of traffic will break up the slab and the pavement will fail. A rigid base course built on a strong foundation, with enough surface and subsurface drainage, will not be broken up in this way.

If the pieces of aggregate in a crushed aggregate base course are not forced tightly together by rolling, they will not be locked together and the base will not spread the surface loads effectively. Poor compaction of the base will also allow muddy material to be forced into the base from below. The pieces of aggregate will then move under the action of traffic, and the base will fail.

If the soil particles and pieces of aggregate in a stabilized base are not held together tightly by the cementing material, the base will not spread the surface loads properly and is likely to fail.

In order that a base may get uniform support from the subgrade, the subgrade must be shaped and compacted so that no water will collect beneath the base. The subgrade surface must be free from ruts or other low places that will hold water. Subdrains must be put in to remove any water coming into the subgrade from below or along the sides. If a subbase is used, the materials must be well graded and compacted so as to give uniform support to the base.

<u>Cement Concrete Base and Header Curb</u>

4. In general, the equipment, construction methods, and duties of the Inspectors on a base course of plain portland cement concrete are the same as those on reinforced cement concrete pavement (Chapter VII). Details of the requirements are given in the Specifications. Allowable variations in surface smoothness are greater for a base than for a pavement. When the surface of the base is checked with a 16-foot straightedge (a 10-foot straightedge on a vertical curve), the variation must not be more than 1/4-inch at a high spot nor more than 3/8-inch at a low spot. However, forms should be set and checked carefully. The surface of the base should be tested for long waves by stringlining. If any waves are left in the base, they will affect the bituminous concrete surface course and the pavement will have poor riding qualities.

The form for the inside face of a header curb* should be set about 1/8-inch higher than the form for the edge of the pavement, and the top surface of the curb should be finished with the slope so produced. The slope of the finished pavement, after the bituminous concrete surface course is placed, will then continue across the curb without a break.

Where a concrete base is to be surfaced with bituminous concrete, the base should not be given a smooth finish. After the concrete has been finished to the proper grade, its surface should be roughened slightly. One way is to move a broom made of steel wires across the surface.

The treated surface should be rough enough to permit the particles of aggregate in the binder course* of the bituminous surfacing to key* into the base. Keying* helps the tack coat prevent movement of the bituminous surfacing under the shoving action of traffic, which occurs on steep grades and at traffic lights and stop signs where drivers apply their brakes.

The concrete for a header curb must be placed not more than 45 minutes after the concrete for the base course is placed. When calcium chloride is used for cold weather curing, this time is reduced to 30 minutes. If calcium chloride is used in the base concrete during normal weather, the curb concrete must be placed not more than 20 minutes after the base concrete. If the base concrete has taken its final set, the curb concrete may not bond to it and the curb may come loose from the base.

The Specifications allow forms to be removed from concrete base after 18 hours. Curing is the same as for concrete pavement. Membrane curing should not be permitted, as it may interfere with bonding of the bituminous surfacing to the concrete.

Where asphaltic concrete surfacing is to be laid on a concrete base course, joints and cracks in the base may be sealed with asphalt having the same penetration grade as that to be used in the surfacing. Asphalt should not be heated above 500 degrees. At a higher temperature, it may become hard and brittle.

A concrete base course cannot be opened to traffic until after 10 days when regular portland cement is used and after 3 days when high-early-strength cement is used. The District Engineer will not permit traffic on the base until the results of beam tests show that the modulus of rupture is at least 500 psi (pounds per square inch) for a Type A base or at least 400 psi for a Type B base.

Subgrade for Crushed Aggregate Base Course

5. A crushed aggregate base course is used very often in Pennsylvania for improving an old road. The purpose of such a base course is to make the old road stronger and wider, where it is cheaper to rebuild the old road than to build a new one. To get good results, a crushed aggregate base course must be built right. Careful inspection is necessary.

As a rule, the subgrade under the old road has been fully compacted by many years of traffic. The subgrade under any new section must be equally well compacted by rolling. If it is not, the base built on it will settle under traffic and a poor riding surface will result. Special attention must be given to any new sections where high spots in the old road have been cut down, where the road has been relocated, or where there is widening.

Before a crushed aggregate base is built, it is important to have a firm, uniform, and well-drained subgrade or subbase. After the base has been completed, it will spread the load over the subgrade or subbase. While the base is being built, however, the surface on which the work is being done must be firm enough to hold up the rollers without moving. If any place on the surface of the subgrade or subbase is pushed down when the roller wheel passes over it, it will move after the stone has been placed and the stone will not be properly keyed and compacted.

The subgrade surface must be graded so that all water will run to the edges. There must not be any ruts or other low spots that will hold water. The subgrade must be brought to the best moisture content for full compaction and rolled until it is firm. If it is too wet, it must be dried out before being rolled. If it is too dry, it must be sprinkled with water, a little at a time, until it is just damp enough to permit the rollers to compact it. If the material at any spot is so soft that it moves when the roller wheel passes over it, the soft material must be dug out and drier subgrade material used to fill the holes. Material that is suitable for a subbase or base must not be used to fill holes or ruts or to bring the subgrade surface up to grade. Water soaks through this type of material, collects in or below it, and makes a soft spot in the subgrade.

Before any other work is done, the subgrade must be brought to perfect grade, have a good drainage system, and be fully compacted. The Contractor must not be allowed to put any subbase or base material on a subgrade that is rutted, spongy, or frozen. A frozen subgrade loses density and must be rolled again after it has thawed out.

Drainage Under Crushed Aggregate Base

6. When a subbase is used, it must usually have the same thickness over the whole width of the pavement, including the part which will be under the shoulders. If the subgrade has the right grade, water that gets through a crushed aggregate base will pass slowly through the subbase and then run along the top of the subgrade to the drainage ditches. In order that the base will have uniform thickness, the surface of the subbase must have the right grade.

If no subbase is used, enough drains must run through the shoulders to allow water to get out of the base. Drains must be built through the shoulders* on both sides of the base at all low points and not more than 200 feet apart between high points and low points. These drains must be built so that they will get water away from the base as fast as possible, both during construction and after the work is completed.

Subgrade drains may be placed in a herringbone pattern, when directed by the Assistant District Construction Engineer. Construction details are given in the Specifications.

The Assistant District Construction Engineer will show the Inspector-in-Charge where subgrade drains are to be located. The locations must then be noted by sketches and stations in the Inspector's field notebooks. The

outlets must be marked, usually with painted stakes. These locations must also be recorded by final-plan stations and revised straight-line stations in order that permanent outlet markers can be placed and the outlets kept open during maintenance operations.

During construction, the Contractor must keep the subgrade drained at all times.

Shoulders

7. In the construction of a crushed aggregate base, the shoulders act as forms that hold the aggregate in place while it is being compacted. For this reason, the shoulders must be built to their full width and to a depth equal to that of the aggregate being placed, and must be fully compacted before construction of the base is started. After a shoulder has been built and compacted to the grade of the completed base, the inside edges must be trimmed to neat lines which are as nearly straight up and down as possible. The distance between the shoulders must be equal to the required width of the base. This should be at least the width of the surface course plus twice the thickness of the base course. The extra width is necessary to spread the loads from wheels which travel along the edges of the surface course.

When a shoulder is built on a subbase, care must be taken not to mix dirt from the subgrade with the subbase material, since the dirt would clog the subbase material so that it would not drain. If the subbase material gets churned up and subgrade material gets mixed in with it, the Contractor must remove the dirty subbase material and replace it with clean material.

Stabilized shoulders are built of two or more layers of granular material, from a source approved by the Laboratory, which meets Specification requirements and which has been approved by the Soils Engineer or Materials Engineer before delivery to the job. When the top layer of granular material will not stay in place under traffic, or when it washes away, the Engineer may direct the Contractor to add an approved binding material to stabilize it.

A paved shoulder is built with a base course at least 8 inches thick. This course may be a crushed aggregate base, Type B; a soil-cement base; or a soil-bituminous base. The base for the shoulder is primed with up to 0.2 gallon per square yard of bituminous material, and the surfacing is a 2-inch layer of Special ID-2 binder course mixture with a seal coat.

Blanket or Bedding Course

8. After the shoulders have been built and the inside edges trimmed, and the subgrade or subbase between the shoulders has been brought to perfect condition, a blanket course is placed. This is a layer of fine granular material called stone screenings*. It is 2 inches thick when placed directly on the subgrade and 1 inch thick when placed on a subbase or on existing paving.

The blanket course serves two purposes. (1) It acts as an inverted choke* for the base course, and helps to lock the bottom pieces of base course

aggregate in place. (2) It keeps muddy material from working up into the base from below. If this muddy material were to get into the base, the pieces of aggregate could easily slide on one another and move under the action of traffic.

The fine granular material in the blanket course should not be placed too far ahead of the aggregate for the base course, because it gets dirty and rutted when trucks run over it. The blanket course must have uniform thickness and an even surface when the base course is placed.

Requirements of Crushed Aggregate

9. The Specifications describe the types of crushed stone and crushed slag that may be used for crushed aggregate base courses. They also give the size and grading requirements for each type. For any crushed aggregate base course, it is necessary to use two aggregate sizes classed as coarse material and fine material. The gradation requirements for each size are very important, and the aggregates delivered first should be tested as soon as they are received on the job.

Spreading Aggregate (See VI-0B,C,D)

10. When starting to build a base, it is a good idea to spread a small amount of aggregate to a loose depth about an inch greater than the desired thickness of the compacted base. This aggregate should be rolled thoroughly, and the compacted thickness should be checked by forking out the coarse aggregate in the middle of the lane, scraping away the fine material at the bottom, placing a straightedge across the hole, and measuring from the bottom of the straightedge down to the surface of the subgrade or subbase. From this measurement, the aggregate spreader can be set to give the right thickness of compacted base.

While aggregate is being spread, the box on the spreader should be kept as full as possible. (Except when the spreader is being moved back to work on another lane). Having the box full helps to keep the thickness of spread the same and also helps to prevent segregation. If any fine material was mixed in with the aggregate and stayed in the bottom of a truck, as much of it as possible should be kept out of the spreader. If such fine material is allowed to go through the spreader and makes a pocket of fines in the base, that pocket must be dug out and backfilled with clean aggregate.

Aggregate must never be dumped in piles on the subbase or subgrade. Doing this segregates the aggregate and makes for a poor grade after rolling.

The surface of each layer of aggregate must be brought to perfect grade before the layer is rolled. Stringlines that are offset on each side of the roadway should be used to check the grade. Pins for stringlines should be about 50 feet apart on a tangent and 25 feet apart on a curve. After lines have been stretched tightly on the pins, another line running across the road can be moved on them by a man on each side. As these men walk along, one of

them can judge the uniformity of the grade. When checking the grade of the spread aggregate, allowance must be made for settlement of the surface during compaction. This allowance is based on the measured thickness of a test portion of the course. Surface of the aggregate must be checked with a straightedge to make sure that there are no waves. If the pavement is to have a crowned cross section, a crown template (crown board) having the right shape, must be used to check the crown.

Rolling Crushed Aggregate Without Vibration

11. The material for a crushed aggregate base course may be compacted by rolling without vibration or by the use of vibratory equipment before final rolling. When the aggregate is to be compacted by rolling only, the base must be built up in layers that are usually not more than 6 inches thick. This limit is necessary because a thick layer of crushed stone or slag cannot be fully compacted by rolling. The pieces of aggregate "bridge" at the bottom of the layer and large spaces are left between these pieces. Later, the vibrations set up by traffic cause these pieces to change their positions. They than become loose, and this "unlocking" causes weak spots in the base. When the total thickness of a Crushed Aggregate Base Course, Type AP, is to be 12 inches, as is usually the case, the compacted thickness of the bottom layer, including the initial layer of fine material, is made 5 inches; and the compacted thickness of the middle layer is then 4 inches.

The aggregate at the edges of the base must be rolled first. On superelevated curves, the rolling should commence along the lower edge of the roadway and progress slowly to the high side. On the first pass, the roller wheel may overlap the shoulder. It is very important that the roller move slowly, especially on the first pass. It is good practice to keep the rolling speed down to about 60 feet per minute, and lower speeds are better. Fast rolling makes waves in the base. In fact, the surface of carefully spread aggregate can be spoiled by fast rolling. When the direction of rolling is reversed, especially on loose stone, the roller must be stopped and started gradually and carefully.

If, during rolling, there is any place where the aggregate gives under the roller and then springs back, rolling at that place should be stopped. Something is wrong with the subgrade or subbase there. Either the subgrade or subbase must be allowed to dry out, or the aggregate must be forked out and the soft spot in the subgrade or subbase fixed. Poor subgrade material should be replaced with good subgrade material; and poor subbase material replaced with good subbase material. A soft spot in the subgrade or subbase should not be fixed by backfilling with crushed stone or screenings, as doing this will lead to trouble later. Any material dug out must be thrown directly on a truck; it should not be allowed to get mixed with the nearby base material.

The aggregate must be rolled until the pieces do not move, but it must not be overrolled. If the pieces at the top of a layer start to break down and the spaces between the large pieces on the surface begin to get filled, the rolling should be stopped. This breakage has to be watched very carefully with some kinds of stone and with slag.

If, after several passes of the roller, the aggregate is still loose and moves under the roller, and is breaking up on the surface, the rolling should be stopped and the conditions reported right away to the Assistant District Construction Engineer. A sample of the aggregate should be taken and tested to make sure that the material being used meets the Specifications. After a section of base has been rolled until the pieces are compacted and keyed so that they do not move under the roller, the ends of the section must be marked with red flags. If they are not marked, fine material may be spread on aggregate that is not fully rolled.

After the base has been rolled, its surface must be checked with straight-edges and, in the case of a crowned cross section, with crown templates. All corrections must be made at this time, as even small corrections cannot be made after the spaces between the pieces of aggregate have been filled (choked) with fine material. At any high or low place the aggregate must be loosened with stone forks. At a high place the extra material must be forked out; at a low place aggregate must be added from piles properly stockpiled on dumping plates outside the roadway. The repaired places then must be fully rolled and rechecked.

Several trial corrections may have to be made to get the grade right. The surface of the base must meet the Specification requirements at every point, and it must be smooth and without waves, since any bumps or waves will show up in the surface course under traffic.

Placing Fine Material in Crushed Aggregate Base

12. As soon as possible after the surface of a layer of coarse material has been fully compacted and keyed, the spaces between the pieces must be entirely filled (choked) with dry screenings. When a layer is fully choked, it will shed almost all rain; but rain that seeps through an unchoked base course will soak into the subgrade and soften it. It takes a long time for a wet subgrade covered with a base course to dry out. When a soft subgrade makes the aggregate in the base course springy under a roller, rolling must be postponed. Unless the pieces of aggregate can be firmly keyed in place, by compacting them when they are confined between the roller wheels and a hard subgrade, the base will be weak.

The screenings must be dry, so that they will sift down to the bottom of the layer of coarse material. If they are damp in the truck, they must be spread in a very thin layer on top of the coarse material and left there until they are dry enough for use. When the screenings are dry enough not to cake when squeezed in the hand, they can be broomed over the surface of the layer until they disappear between the pieces of coarse material. Construction will be speeded up if stockpiles of screenings are kept covered with tarpaulins or plastic covers so that the screenings don't get wet.

Screenings must never be dumped in piles on top of the coarse material. They must be spread in a thin layer and broomed in a little at a time. An approved lime spreader, or a similar type of machine generally gives good results. The layer should be rolled while the screenings are being spread,

Base Course

Spreading Base Course

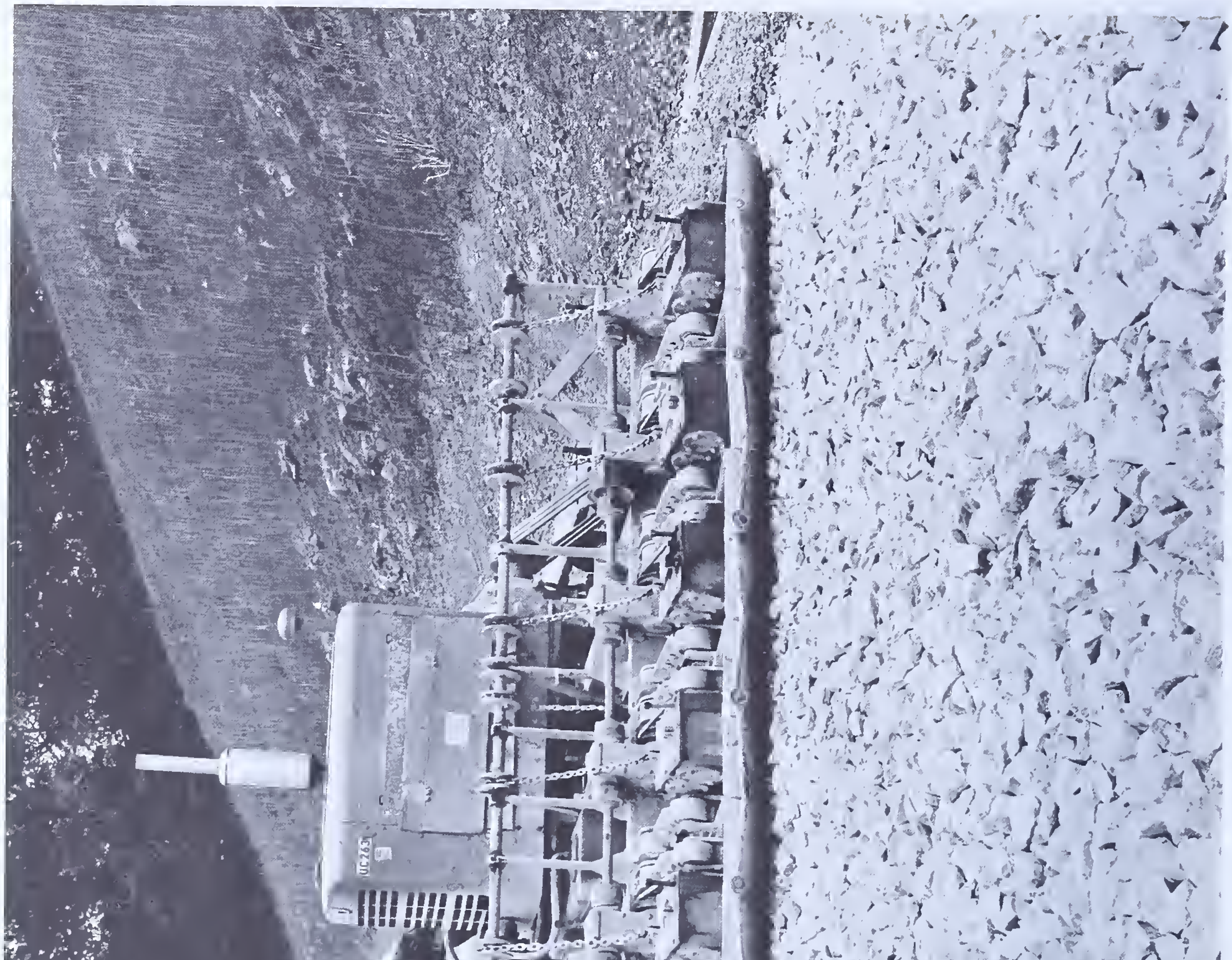
Placing Screenings

Brooming & Rolling Fines

Straight edging lane

Test Hole

Sieve Test



Compacting Base Course

CHAPTER VI

BASE COURSES

Importance of Base Courses (See VI-0A)

1. If a pavement built of a strong base* course and a surfacing of asphaltic concrete* is placed on a good subgrade* or subbase*, it will carry any normal traffic load and will last a long time. Many of the older roads in Pennsylvania were built in this way and are still giving good service under heavy traffic. To get good results uniformly, the base course, or base, must be well constructed, and have uniform strength. If there are weak places in the base because it does not have the full thickness, or because the materials are of poor quality, or are not fully compacted*, traffic will find these places and push the pavement surface down. This movement will cause a bump or a pothole. To fix it will cost money.

Types of Bases

2. Many types of bases will give good service. Any base must be built so that the pressure of a truck tire applied to a small area on the surface of the road will be spread over a much larger area of the subbase or subgrade, which can then support the truck without moving down. The conditions are like these: If a man steps directly on soft mud, his foot will sink in. However, if he lays a wide board on the mud and steps on it, the board will sink very little. The man's weight is spread out by the board. A base course acts in much the same way in spreading the weight of a truck.

Bases are of three general types. One type is the rigid base, which spreads the load by slab action. A base of portland cement concrete is an example. Another type is the crushed aggregate base, which spreads the load because the edges and corners of the pieces of aggregate lock the pieces together. The Specifications describe a Crushed Stone Base Course and several types of Crushed Aggregate Base Courses. In this Construction Manual, the general term "crushed aggregate base course" will be used to include the Crushed Stone Base Course, the Crushed Aggregate Base Course, Type A or Type B, and the lower courses of the Crushed Aggregate Base Course, Type AP. Also, the term "aggregate" will be used to mean stone or slag.

A third type of base is one in which soil particles and pieces of aggregate are held tightly together by some cementing material, such as portland cement*, lime-pozzolan*, asphalt*, or tar*. A base of this type is called a stabilized base.

Causes of Failure of Base Courses

3. The life of the surface course depends on the base; if the base fails, the surface course will fail. It is important that the base be supported uniformly by the subbase or subgrade. The purpose of the base is to spread

NOTE: Words marked with an * are explained in the Word List at the back of this book.

loads on the pavement over the subbase or subgrade. Even a rigid base cannot act as a bridge over a soft or weak spot in the subgrade. If a rigid base is built on a subgrade which has a lot of clay or silt in it, the base may break up because of pumping action of the subgrade under traffic. It is likely that water will get into the subgrade from the surface, from the shoulders, or from below. The fines* in the subgrade material will then become muddy, and the action of traffic will force some of the muddy material out from under the base slab. The slab will then start to move or rock. Subgrade material will be pumped up through joints or cracks or will be blown out from under the edges of the slab. After uniformity of support from the subgrade is lost, the weight of traffic will break up the slab and the pavement will fail. A rigid base course built on a strong foundation, with enough surface and subsurface drainage, will not be broken up in this way.

If the pieces of aggregate in a crushed aggregate base course are not forced tightly together by rolling, they will not be locked together and the base will not spread the surface loads effectively. Poor compaction of the base will also allow muddy material to be forced into the base from below. The pieces of aggregate will then move under the action of traffic, and the base will fail.

If the soil particles and pieces of aggregate in a stabilized base are not held together tightly by the cementing material, the base will not spread the surface loads properly and is likely to fail.

In order that a base may get uniform support from the subgrade, the subgrade must be shaped and compacted so that no water will collect beneath the base. The subgrade surface must be free from ruts or other low places that will hold water. Subdrains must be put in to remove any water coming into the subgrade from below or along the sides. If a subbase is used, the materials must be well graded and compacted so as to give uniform support to the base.

Cement Concrete Base and Header Curb

4. In general, the equipment, construction methods, and duties of the Inspectors on a base course of plain portland cement concrete are the same as those on reinforced cement concrete pavement (Chapter VII). Details of the requirements are given in the Specifications. Allowable variations in surface smoothness are greater for a base than for a pavement. When the surface of the base is checked with a 16-foot straightedge (a 10-foot straightedge on a vertical curve), the variation must not be more than 1/4-inch at a high spot nor more than 3/8-inch at a low spot. However, forms should be set and checked carefully. The surface of the base should be tested for long waves by stringlining. If any waves are left in the base, they will affect the bituminous concrete surface course and the pavement will have poor riding qualities.

The form for the inside face of a header curb* should be set about 1/8-inch higher than the form for the edge of the pavement, and the top surface of the curb should be finished with the slope so produced. The slope of the finished pavement, after the bituminous concrete surface course is placed, will then continue across the curb without a break.

Where a concrete base is to be surfaced with bituminous concrete, the base should not be given a smooth finish. After the concrete has been finished to the proper grade, its surface should be roughened slightly. One way is to move a broom made of steel wires across the surface.

The treated surface should be rough enough to permit the particles of aggregate in the binder course* of the bituminous surfacing to key* into the base. Keying* helps the tack coat prevent movement of the bituminous surfacing under the shoving action of traffic, which occurs on steep grades and at traffic lights and stop signs where drivers apply their brakes.

The concrete for a header curb must be placed not more than 45 minutes after the concrete for the base course is placed. When calcium chloride is used for cold weather curing, this time is reduced to 30 minutes. If calcium chloride is used in the base concrete during normal weather, the curb concrete must be placed not more than 20 minutes after the base concrete. If the base concrete has taken its final set, the curb concrete may not bond to it and the curb may come loose from the base.

The Specifications allow forms to be removed from concrete base after 18 hours. Curing is the same as for concrete pavement. Membrane curing should not be permitted, as it may interfere with bonding of the bituminous surfacing to the concrete.

Where asphaltic concrete surfacing is to be laid on a concrete base course, joints and cracks in the base may be sealed with asphalt having the same penetration grade as that to be used in the surfacing. Asphalt should not be heated above 500 degrees. At a higher temperature, it may become hard and brittle.

A concrete base course cannot be opened to traffic until after 10 days when regular portland cement is used and after 3 days when high-early-strength cement is used. The District Engineer will not permit traffic on the base until the results of beam tests show that the modulus of rupture is at least 500 psi (pounds per square inch) for a Type A base or at least 400 psi for a Type B base.

Subgrade for Crushed Aggregate Base Course

5. A crushed aggregate base course is used very often in Pennsylvania for improving an old road. The purpose of such a base course is to make the old road stronger and wider, where it is cheaper to rebuild the old road than to build a new one. To get good results, a crushed aggregate base course must be built right. Careful inspection is necessary.

As a rule, the subgrade under the old road has been fully compacted by many years of traffic. The subgrade under any new section must be equally well compacted by rolling. If it is not, the base built on it will settle under traffic and a poor riding surface will result. Special attention must be given to any new sections where high spots in the old road have been cut down, where the road has been relocated, or where there is widening.

Before a crushed aggregate base is built, it is important to have a firm, uniform, and well-drained subgrade or subbase. After the base has been completed, it will spread the load over the subgrade or subbase. While the base is being built, however, the surface on which the work is being done must be firm enough to hold up the rollers without moving. If any place on the surface of the subgrade or subbase is pushed down when the roller wheel passes over it, it will move after the stone has been placed and the stone will not be properly keyed and compacted.

The subgrade surface must be graded so that all water will run to the edges. There must not be any ruts or other low spots that will hold water. The subgrade must be brought to the best moisture content for full compaction and rolled until it is firm. If it is too wet, it must be dried out before being rolled. If it is too dry, it must be sprinkled with water, a little at a time, until it is just damp enough to permit the rollers to compact it. If the material at any spot is so soft that it moves when the roller wheel passes over it, the soft material must be dug out and drier subgrade material used to fill the holes. Material that is suitable for a subbase or base must not be used to fill holes or ruts or to bring the subgrade surface up to grade. Water soaks through this type of material, collects in or below it, and makes a soft spot in the subgrade.

Before any other work is done, the subgrade must be brought to perfect grade, have a good drainage system, and be fully compacted. The Contractor must not be allowed to put any subbase or base material on a subgrade that is rutted, spongy, or frozen. A frozen subgrade loses density and must be rolled again after it has thawed out.

Drainage Under Crushed Aggregate Base

6. When a subbase is used, it must usually have the same thickness over the whole width of the pavement, including the part which will be under the shoulders. If the subgrade has the right grade, water that gets through a crushed aggregate base will pass slowly through the subbase and then run along the top of the subgrade to the drainage ditches. In order that the base will have uniform thickness, the surface of the subbase must have the right grade.

If no subbase is used, enough drains must run through the shoulders to allow water to get out of the base. Drains must be built through the shoulders* on both sides of the base at all low points and not more than 200 feet apart between high points and low points. These drains must be built so that they will get water away from the base as fast as possible, both during construction and after the work is completed.

Subgrade drains may be placed in a herringbone pattern, when directed by the Assistant District Construction Engineer. Construction details are given in the Specifications.

The Assistant District Construction Engineer will show the Inspector-in-Charge where subgrade drains are to be located. The locations must then be noted by sketches and stations in the Inspector's field notebooks. The

outlets must be marked, usually with painted stakes. These locations must also be recorded by final-plan stations and revised straight-line stations in order that permanent outlet markers can be placed and the outlets kept open during maintenance operations.

During construction, the Contractor must keep the subgrade drained at all times.

Shoulders

7. In the construction of a crushed aggregate base, the shoulders act as forms that hold the aggregate in place while it is being compacted. For this reason, the shoulders must be built to their full width and to a depth equal to that of the aggregate being placed, and must be fully compacted before construction of the base is started. After a shoulder has been built and compacted to the grade of the completed base, the inside edges must be trimmed to neat lines which are as nearly straight up and down as possible. The distance between the shoulders must be equal to the required width of the base. This should be at least the width of the surface course plus twice the thickness of the base course. The extra width is necessary to spread the loads from wheels which travel along the edges of the surface course.

When a shoulder is built on a subbase, care must be taken not to mix dirt from the subgrade with the subbase material, since the dirt would clog the subbase material so that it would not drain. If the subbase material gets churned up and subgrade material gets mixed in with it, the Contractor must remove the dirty subbase material and replace it with clean material.

Stabilized shoulders are built of two or more layers of granular material, from a source approved by the Laboratory, which meets Specification requirements and which has been approved by the Soils Engineer or Materials Engineer before delivery to the job. When the top layer of granular material will not stay in place under traffic, or when it washes away, the Engineer may direct the Contractor to add an approved binding material to stabilize it.

A paved shoulder is built with a base course at least 8 inches thick. This course may be a crushed aggregate base, Type B; a soil-cement base; or a soil-bituminous base. The base for the shoulder is primed with up to 0.2 gallon per square yard of bituminous material, and the surfacing is a 2-inch layer of Special ID-2 binder course mixture with a seal coat.

Blanket or Bedding Course

8. After the shoulders have been built and the inside edges trimmed, and the subgrade or subbase between the shoulders has been brought to perfect condition, a blanket course is placed. This is a layer of fine granular material called stone screenings*. It is 2 inches thick when placed directly on the subgrade and 1 inch thick when placed on a subbase or on existing paving.

The blanket course serves two purposes. (1) It acts as an inverted choke* for the base course, and helps to lock the bottom pieces of base course

aggregate in place. (2) It keeps muddy material from working up into the base from below. If this muddy material were to get into the base, the pieces of aggregate could easily slide on one another and move under the action of traffic.

The fine granular material in the blanket course should not be placed too far ahead of the aggregate for the base course, because it gets dirty and rutted when trucks run over it. The blanket course must have uniform thickness and an even surface when the base course is placed.

Requirements of Crushed Aggregate

9. The Specifications describe the types of crushed stone and crushed slag that may be used for crushed aggregate base courses. They also give the size and grading requirements for each type. For any crushed aggregate base course, it is necessary to use two aggregate sizes classed as coarse material and fine material. The gradation requirements for each size are very important, and the aggregates delivered first should be tested as soon as they are received on the job.

Spreading Aggregate (See VI-OB,C,D)

10. When starting to build a base, it is a good idea to spread a small amount of aggregate to a loose depth about an inch greater than the desired thickness of the compacted base. This aggregate should be rolled thoroughly, and the compacted thickness should be checked by forking out the coarse aggregate in the middle of the lane, scraping away the fine material at the bottom, placing a straightedge across the hole, and measuring from the bottom of the straightedge down to the surface of the subgrade or subbase. From this measurement, the aggregate spreader can be set to give the right thickness of compacted base.

While aggregate is being spread, the box on the spreader should be kept as full as possible. (Except when the spreader is being moved back to work on another lane). Having the box full helps to keep the thickness of spread the same and also helps to prevent segregation. If any fine material was mixed in with the aggregate and stayed in the bottom of a truck, as much of it as possible should be kept out of the spreader. If such fine material is allowed to go through the spreader and makes a pocket of fines in the base, that pocket must be dug out and backfilled with clean aggregate.

Aggregate must never be dumped in piles on the subbase or subgrade. Doing this segregates the aggregate and makes for a poor grade after rolling.

The surface of each layer of aggregate must be brought to perfect grade before the layer is rolled. Stringlines that are offset on each side of the roadway should be used to check the grade. Pins for stringlines should be about 50 feet apart on a tangent and 25 feet apart on a curve. After lines have been stretched tightly on the pins, another line running across the road can be moved on them by a man on each side. As these men walk along, one of

them can judge the uniformity of the grade. When checking the grade of the spread aggregate, allowance must be made for settlement of the surface during compaction. This allowance is based on the measured thickness of a test portion of the course. Surface of the aggregate must be checked with a straightedge to make sure that there are no waves. If the pavement is to have a crowned cross section, a crown template (crown board) having the right shape, must be used to check the crown.

Rolling Crushed Aggregate Without Vibration

11. The material for a crushed aggregate base course may be compacted by rolling without vibration or by the use of vibratory equipment before final rolling. When the aggregate is to be compacted by rolling only, the base must be built up in layers that are usually not more than 6 inches thick. This limit is necessary because a thick layer of crushed stone or slag cannot be fully compacted by rolling. The pieces of aggregate "bridge" at the bottom of the layer and large spaces are left between these pieces. Later, the vibrations set up by traffic cause these pieces to change their positions. They than become loose, and this "unlocking" causes weak spots in the base. When the total thickness of a Crushed Aggregate Base Course, Type AP, is to be 12 inches, as is usually the case, the compacted thickness of the bottom layer, including the initial layer of fine material, is made 5 inches; and the compacted thickness of the middle layer is then 4 inches.

The aggregate at the edges of the base must be rolled first. On super-elevated curves, the rolling should commence along the lower edge of the roadway and progress slowly to the high side. On the first pass, the roller wheel may overlap the shoulder. It is very important that the roller move slowly, especially on the first pass. It is good practice to keep the rolling speed down to about 60 feet per minute, and lower speeds are better. Fast rolling makes waves in the base. In fact, the surface of carefully spread aggregate can be spoiled by fast rolling. When the direction of rolling is reversed, especially on loose stone, the roller must be stopped and started gradually and carefully.

If, during rolling, there is any place where the aggregate gives under the roller and then springs back, rolling at that place should be stopped. Something is wrong with the subgrade or subbase there. Either the subgrade or subbase must be allowed to dry out, or the aggregate must be forked out and the soft spot in the subgrade or subbase fixed. Poor subgrade material should be replaced with good subgrade material; and poor subbase material replaced with good subbase material. A soft spot in the subgrade or subbase should not be fixed by backfilling with crushed stone or screenings, as doing this will lead to trouble later. Any material dug out must be thrown directly on a truck; it should not be allowed to get mixed with the nearby base material.

The aggregate must be rolled until the pieces do not move, but it must not be overrolled. If the pieces at the top of a layer start to break down and the spaces between the large pieces on the surface begin to get filled, the rolling should be stopped. This breakage has to be watched very carefully with some kinds of stone and with slag.

If, after several passes of the roller, the aggregate is still loose and moves under the roller, and is breaking up on the surface, the rolling should be stopped and the conditions reported right away to the Assistant District Construction Engineer. A sample of the aggregate should be taken and tested to make sure that the material being used meets the Specifications. After a section of base has been rolled until the pieces are compacted and keyed so that they do not move under the roller, the ends of the section must be marked with red flags. If they are not marked, fine material may be spread on aggregate that is not fully rolled.

After the base has been rolled, its surface must be checked with straightedges and, in the case of a crowned cross section, with crown templates. All corrections must be made at this time, as even small corrections cannot be made after the spaces between the pieces of aggregate have been filled (choked) with fine material. At any high or low place the aggregate must be loosened with stone forks. At a high place the extra material must be forked out; at a low place aggregate must be added from piles properly stockpiled on dumping plates outside the roadway. The repaired places then must be fully rolled and rechecked.

Several trial corrections may have to be made to get the grade right. The surface of the base must meet the Specification requirements at every point, and it must be smooth and without waves, since any bumps or waves will show up in the surface course under traffic.

<u>Placing Fine Material in Crushed Aggregate Base</u>

12. As soon as possible after the surface of a layer of coarse material has been fully compacted and keyed, the spaces between the pieces must be entirely filled (choked) with dry screenings. When a layer is fully choked, it will shed almost all rain; but rain that seeps through an unchoked base course will soak into the subgrade and soften it. It takes a long time for a wet subgrade covered with a base course to dry out. When a soft subgrade makes the aggregate in the base course springy under a roller, rolling must be postponed. Unless the pieces of aggregate can be firmly keyed in place, by compacting them when they are confined between the roller wheels and a hard subgrade, the base will be weak.

The screenings must be dry, so that they will sift down to the bottom of the layer of coarse material. If they are damp in the truck, they must be spread in a very thin layer on top of the coarse material and left there until they are dry enough for use. When the screenings are dry enough not to cake when squeezed in the hand, they can be broomed over the surface of the layer until they disappear between the pieces of coarse material. Construction will be speeded up if stockpiles of screenings are kept covered with tarpaulins or plastic covers so that the screenings don't get wet.

Screenings must never be dumped in piles on top of the coarse material. They must be spread in a thin layer and broomed in a little at a time. An approved lime spreader, or a similar type of machine generally gives good results. The layer should be rolled while the screenings are being spread,

since the vibration caused by rolling helps shake the screenings into the spaces between the pieces of coarse material at the bottom of the layer. Spreading of screenings, brooming, and rolling should be continued until all the spaces between the pieces of coarse material, from the bottom up, are filled with screenings. The screenings lock the stones together and made the base much stronger. At the same time they make the base course more waterproof so water used in the final operation will not run through the base course and soften the subgrade. When screenings are rolled into the spaces between the large pieces without the use of vibratory equipment, about 20 percent of all the aggregate, by weight, is screenings.

Finishing Operations

13. When the screenings have filled all the spaces between the pieces of coarse material in a layer of the base course, the layer must be sprinkled with water from a sprinkler tank mounted on a rubber-tired truck. After each pass of the sprinkler the surface of the layer should be broomed. At any place where the screenings have dropped down below the surface of the layer, more screenings should be added. If a mat of screenings is formed on top of the coarse material, the mat must be broken up, and the matted material thrown beyond the side of the roadway. Sprinkling and brooming should be continued until all the spaces between the pieces of coarse material are filled with screenings and water stays on top of the layer. The surface must then be rolled. The roller should start at the sides of the roadway and work to the center.

When a Crushed Aggregate Base Course, Type B, is built in two or more layers, sprinkling with water and extra rolling are necessary only for the top layer. Type A requires water on both layers.

The surface of any crushed aggregate base built in one layer or the surface of the top layer of a crushed aggregate base built in two or more layers must be finished with a rolled layer of grout composed of water and screenings. Enough water and screenings should be used in the grout to make it about as stiff as heavy cream and to permit a wave of grout about 1/4 inch high to be pushed in front of the roller. It is best to use the sprinkler and roller together over the whole width of the base on sections not more than about 300 feet long. If a section is too long, the water will be lost before it is mixed with the screenings by the roller to make the grout. To keep about 1/4 inch of grout in front of the roller, it may be necessary to add screenings or to spread out the grout by brooming.

After a whole section of base has been grouted, the extra grout should be broomed from the center of the base over the sides. The base must then be allowed to dry (cure out). When dry, the grout should set up hard, almost like concrete. If the screenings are loose and dusty when they become dry, limestone screenings must be mixed with the fine material before any more of it is used. A good base should look like rough concrete, with the top surface of the large pieces of aggregate showing.

Compacting Crushed Aggregate Base With Vibration (See VI-OE)

14. When pan-type vibrators or vibrating rollers are used, a crushed aggregate base course up to 10 inches thick may be built in one layer. If more

than one layer is used, no layer should have a compacted thickness greater than 6 inches. The aggregate is spread with a stone spreader, and the details of checking its thickness and most of the steps in building the base are the same as those without vibration.

After the aggregate has been spread and its thickness checked, it is compacted and keyed by several passes of the vibratory equipment. It then receives its final compaction by rolling as described when vibratory equipment is not used. After the large pieces of aggregate are keyed, screenings are vibrated into the spaces between these pieces. Screenings must be dry enough to permit the vibration to shake them down to the bottom of a thick layer of coarse material. If they are damp, they must be spread in a very thin layer and allowed to dry before vibration is started. If the vibratory equipment leaves a crust of screenings on top of the coarse material, the screenings are too damp and must be dried some more.

When the screenings are dry enough, a layer of screenings about one-fifth the thickness of the base can be used for the first spread. After these screenings have been vibrated until they have disappeared, two more layers, each about one-tenth the thickness of the base, can be spread and vibrated. As soon as screenings remain in the spaces between the large pieces at the top of the layer, the vibration should be stopped and the rest of the choking done with a roller. If too many screenings are vibrated into a base, the large pieces will float, that is, the screenings will be forced beneath these pieces, and the keying action weakened. Floating weakens a base greatly. To be on the safe side, it is best to use only the roller on the last layer of screenings. When vibratory equipment is used to help fill the spaces in the coarse material with screenings, from 30 to 35 percent of all the aggregate, by weight, is screenings.

After the dry screenings have been vibrated and rolled into the spaces in the coarse material, the base is completed as described when vibratory equipment is not used.

Checking and Protecting Crushed Aggregate Base

15. Whether or not vibratory equipment is used in building a crushed aggregate base, the portion of the base completed each day must be checked for surface smoothness and thickness as required by the Specifications. After the thickness has been checked by digging test holes and making measurements, the test holes must be filled properly. Coarse material is placed, tamped, and rolled. Then the spaces in the coarse material are filled with screenings, and the surface is saturated with water and rolled until the base is fully compacted. The operations for filling the test holes must be inspected carefully to prevent weak places in the base.

The completed base must be protected from high-speed traffic. When the speed is above about 10 miles per hour, the suction of the tires will pull the screenings out of the spaces between the pieces of coarse material, those pieces will become loose, and the base will start to ravel. On curves, high-speed traffic will loosen the large pieces and push them to the outside of the curve.

Top Layer of Type AP Base Course

16. A Crushed Aggregate Base Course, Type AP, has a top 3-inch layer built of crushed stone or slag bound with bituminous material. This layer is placed over one or two layers of crushed aggregate built like layers of a base consisting entirely of crushed aggregate without bituminous binder. The bituminous-bound top layer can be built either like the binder course of a Bituminous Surface Course ID-2 or like a Bituminous Surface Course DP-1. When the layer is similar to an ID-2 binder course, the construction and inspection methods described in Chapter VIII of this Construction Manual apply. Before the top layer of the base is placed, any loose or matted screenings on the surface of the layer below must be removed. If a power broom is used for this purpose, care must be taken not to loosen any pieces of coarse material.

The following information applies when the top layer of the base course is built like a DP-1 surface course, that is, by the penetration method.

Cleaning and Priming Surface of Lower Layer

17. When the penetration method for a DP-1 surface course is used to construct the top layer of an AP base course, any loose or matted screenings must be cleaned off the surface of the layer below before the aggregate for the penetration layer is placed. The tops of the pieces of coarse material in the lower layer should be showing. Unless forms are used, the shoulders must be brought up to grade, fully compacted, and trimmed to line and grade. The lower layer of the base should be slightly damp when primed. If it is dry, it should be sprinkled lightly with water to lay the dust.

The specified and approved tar prime material should not be heated to more than 150 degrees F. Before prime material is applied to the lower layer, the spray bar on the distributor should be tried off the roadway, to make sure that all nozzles are working. When a run is made, the nozzles should spray the surface uniformly. If the prime is in streaks, it should be spread with brooms.

Before a run is started, the distributor should be "strapped" by reading a gage or by measuring down from a reference point in the opening at the top of the distributor to the surface of the bituminous material in the distributor. The distributor should be as level as possible when the measurement is made. The Inspector should measure the length of the run, get the number of square yards of base covered, strap the distributor again, and compute the amount (portion of a gallon) of prime actually applied to one square yard of base. If this amount is within 10 percent of the 0.25 gallon per square yard required by the Specifications, a correction should be made in the rate of application for the next run. If less than 0.20 gallon per square yard has been applied, a second application of prime may be necessary. After the surface has been primed, any pools of prime should be spread out by brooming or blotted with dry sand. The prime must then be allowed to cure before the aggregate for the penetration course is placed, to prevent prime from being

picked up by the tires on the aggregate trucks. If prime is picked up by the tires at any place, a little dry sand should be spread over the prime at that place.

Placing Coarse Material for Penetration Layer

18. Coarse aggregate for the penetration layer of Type AP base course should meet the size and grading requirements specified for No. 3A aggregate. All of this material should be spread with a spreader or tailgated from trucks. If aggregate is dumped in piles, the entire contents of each pile must be forked to another place during spreading. Before full-scale operations begin, a small amount of aggregate should be spread in a layer about 3-1/2 inches deep and thoroughly rolled. A hole should then be dug through the aggregate and a straightedge placed across the hole. The compacted depth of the layer can be found by measuring from the lower edge of the straightedge to the primed surface. If this measured depth is not exactly 3 inches, the depth of the loose stone when first spread should be made more or less than the trial depth so as to give a 3-inch compacted thickness.

The aggregate must be spread to the right grade. The shape of the surface should be checked with stringlines, straightedges, and crown templates (on a crowned cross section). When the grade is perfect, the aggregate should be rolled. On the first pass, the roller should be operated on a very low speed. Fast rolling will make waves in the base, and they will have to be removed. The rollers must be reversed very carefully so that the pieces of aggregate will not be moved after they have been keyed in place. Overrolling of the top layer must not be permitted, since it is easy to crush or "round" aggregate in a layer only 3 inches thick. If the spaces in the coarse material become filled with fines at any place, this choked aggregate must be dug out and replaced with clean material. After the aggregate in the penetration layer has been rolled thoroughly the layer must be checked for grade and thickness.

Measurement of Bituminous Material

19. The number of gallons of bituminous material specified per square yard for AP Base or DP-1 bituminous surface is the gallonage measured at a temperature of 60 degrees F. Since most bituminous materials are heated before using, and the volume increases when the material is heated, the number of heated gallons which must be applied to each square yard is greater than the number of gallons (at 60 degrees F.) which are specified. For instance, if 1.80 gallons per square yard of BM-1 (at 60 degrees F.) was specified, about 1.96 gallons per square yard of 300 degree F. material would have to be applied by the distributor.

Bituminous material such as BM-1 or C-2 is inspected and approved at the refinery. The material is delivered to the job in tankers which hold about 4000 gallons. Each tanker must have a ticket of certification and approval (Form No. 431 B) that has been signed by the Inspector at the refinery. This ticket shows the class and net weight of bituminous material and the specific gravity at 60 degrees F.

To find the number of gallons (at 60 degrees F.) in the tanker, divide the net weight by the weight of one gallon of the material at 60 degrees F. (8.33 x specific gravity at 60 degrees F.) For instance, if the Form 431 showed a net weight of 36,840 pounds of 85/100 asphalt cement (BM-1) and a specific gravity of 1.026 at 60 degrees F., the number of gallons in the tanker would be:

$$\frac{36,840}{8.33 \times 1.026} = 4,311 \text{ gallons at 60 degrees F.}$$

At a specified rate of application of 1.80 gallons per square yard, (for example) the material in the tanker should cover a total area of:

$$\frac{4,311}{1.80} = 2,395 \text{ square yards}$$

Applying Bituminous Material to Aggregate

20. This material from the tanker is applied to the base by distributors which hold about 1200 gallons each. The actual number of gallons per square yard as measured out of the distributor will depend on the temperature at the time the material is sprayed on the base. To control the application so as to get the specified coverage, first find how many gallons per square yard (at 60 degrees F.) are required by the Specifications for the Specific operation (such as 1.70 to 1.85 gallons per square yard of BM-1 for AP Base). Unless otherwise directed, select a rate about in the middle of the range, such as 1.80 gallons per square yard. Measure the actual temperature of the bituminous material in the distributor, then determine the number of gallons of material in the distributor. This may sometimes be read from a gage, but it is best to strap the distributor by measuring from a reference point at the top opening to the surface of the material (not just to the top of the layer of foam). The gallons may then be read from a table which is carried on the distributor. Also, determine the width of the spread of material that will be applied by the spray bar.

Knowing the gallons per square yard (60 degree F. basis), the actual temperature of the material, the number of gallons of material in the distributor, and the width of the spread, the distance the distributor should travel is found by the following procedure:

Step 1. Determine the number of gallons of heated material that must be applied to each square yard.

To do this, multiply the specified number of gallons per square yard at 60 degrees F. by the factor "M" from one of the following tables that corresponds to the actual temperature of the material in the distributor.

Correction Table for BM-1 (Asphalt Cement)

t = actual measured temperature (degrees F.)
m = multiplying factor

t	m	t	m
250	1.068	290	1.083
255	1.070	295	1.085
260	1.072	300	1.087
265	1.074	305	1.089
270	1.076	310	1.091
275	1.0775	315	1.092
280	1.079	320	1.094
285	1.081	325	1.096

Correction Table for C-2 (Cut-Back Emulsified Asphalt)

t	m	t	m
100	1.016	140	1.032
105	1.018	145	1.034
110	1.020	150	1.0365
115	1.022	155	1.039
120	1.024	160	1.041
125	1.026	165	1.043
130	1.028	170	1.045
135	1.030	175	1.047

For example, if 1.80 gallons per square yard of BM-1 at 60 degrees F is specified, and the temperature of the material in the distributor is 285 degrees F., the number of gallons per square yard to be applied is

$$1.80 \times 1.081 = 1.946 \text{ gallons per square yard.}$$

Step 2. Determine width in feet of distributor spray pattern or spread. Divide this width by 9 (number of square feet in one square yard) to find the number of square yards per running foot.

For example: If the distributor spray bars apply asphalt for a width of 12 feet, the number of square yards per running foot is

$$\frac{12}{9} = 1.333$$

Step 3. Determine the number of gallons of material in the distributor. This may be read from an accurate gage, or a measurement may be made from a reference point in the top opening to the surface of the material in the distributor. The number of gallons is then found from an innage table carried on the distributor.

Step 4. Find the number of square yards the distributor load will cover by dividing the number of gallons per square yard (Step 1). For example: If the measured quantity of hot material in the distributor is 1180 gallons at 285 degrees F., and the

corrected number of gallons per square yard is 1.94, the total number of square yards that should be covered is

$$\frac{1180}{1.94} = 608$$

Step 5. Determine how far the distributor should travel by dividing the total square yards that can be covered (Step 4) by the number of square yards per running foot (Step 2). For example: Using the results found for examples given in Steps 4 and 2, the number of feet of travel would be

$$\frac{608}{1.33} = 457$$

After several initial runs the correct speed should be established. However, the limits of each run should be marked, by flags, to make sure that the rate of application is correct.

On short jobs, where a full distributor load is not used from start to finish of the run, the gallons actually used must be found. To do this, repeat Step 3 after the run and subtract the result from the gallonage first measured. Then check the rate of application by dividing the gallons used by the length of the run in feet times the number of square yards per running foot. The result should be the number of gallons specified to be applied to each square yard (Step 1). For example: The distributor is strapped and found to contain 1180 gallons (Step 3). The distributor then makes a run for the full length of the job which is only 300 feet. The distributor is then strapped again and found to contain 410 gallons. The gallonage used is 1180 - 410 or 770 gallons. The number of square yards per running foot is 1.33 (Step 2).

$$\frac{770}{330 \times 1.33} = 1.93 \text{ gallons per square yard.}$$

The Inspector should check the nozzles on the spray bar often to see that the material is flowing through them properly. He should also check the average amount of material actually applied to each square yard on each run. If the spread has been too light, or if it is seen to be uneven, a correction can be made by running the distributor alongside the base and using the hand spray.

Applying Choke Aggregate in Penetration Layer

21. As soon as possible after the bituminous material has been applied to the No. 3A coarse aggregate in the penetration layer of Type AP base, enough No. 2 coarse aggregate should be added to fill the surface voids in

the layer. This choke aggregate should be spread evenly over the surface of the base, and then broomed and rolled into the spaces between the pieces of No. 3A aggregate. The amount of No. 2 aggregate usually needed is about 20 pounds per square yard. Since the choke aggregate should be rolled in before the bituminous material becomes too cool, the length of base treated with bituminous material at one time should be short enough to insure good bonding of the choke aggregate.

Reconstructed Base Course

22. It is sometimes cheapest to build a base for a new road by making use of material already in place in an existing base and surface course. The base for the new road is then called a reconstructed base. The material for a reconstructed base should meet the requirements for a Crushed Aggregate Base Course, Type B.

A reconstructed base should be made thick enough to carry heavy traffic. The proper elevation of the surface of the subgrade depends on the grade and cross section of the surface of the new pavement and the combined thickness of the new pavement and the reconstructed base shown on the Contract Drawings. The quantity of old material available for the base and the quantity of new material needed for it should be determined by a careful inspection in the field. Drainage is of great importance. At low points in the grades, enough drains and outlets must be provided to permit all water to escape.

Materials for Type DG (Dense Graded) Base Course

23. A Crushed Aggregate Base Course, Type DG, consists of a mixture of coarse aggregate, fine aggregate, mineral filler, and water, prepared in a plant. The coarse aggregate and fine aggregate may be crushed stone, gravel, or slag meeting the requirements of the Specifications in regard to quality, size, and grading. The mineral filler must meet the specified requirements for filler in a Bituminous Surface Course JA-1. This filler, which passes a No. 200 sieve, acts as a binder to hold the pieces of aggregate firmly in position after the base is compacted.

The coarse aggregate, fine aggregate, and filler are proportioned separately in accordance with the job mix formula; and these materials are combined with the aid of a fixed amount of water to produce a uniform mixture meeting the specified requirements for gradation and moisture content. Segregation of the materials during hauling and placing must be prevented, as uniform gradation of the material in place is necessary for good results. If the mixture does not contain the right amount of moisture, segregation* is likely to occur. When a sample of the mixture is taken for testing the gradation, any lumps of fine material in the sample must be broken up and mixed with the other material before the sample is quartered* for reducing its volume to testing size.

Placing Mixture for Type DG (Dense Graded) Base

24. As for other types of crushed aggregate base courses, the subgrade or subbase for a Type DG base must be firm and well shaped. If there are any soft or springy places in the subgrade, the poor material must be dug out

and replaced with good subgrade material which must then be fully compacted. The subgrade or subbase for a Type DG base should be only slightly moist when the base mixture is placed on it. If the trucks hauling base mixture to the spreader make ruts in the subgrade or subbase, spreading of the base mixture should be stopped until the ruts have been removed by grading and the subgrade or subbase re-rolled to the density required by the Specifications.

After the subgrade or subbase has been properly prepared, the right thickness of the uncompacted layer of base mixture should be found by trial. First, a small amount of the mixture should be spread to a uniform depth about 1-1/4 times the desired thickness of the compacted layer. For example, if the compacted thickness of the base is to be 6 inches, the trial thickness of the material first spread should be about 5/4 x 6, or 7-1/2 inches. This material should be fully rolled, and the thickness and density checked. To check the thickness, a hole should be dug through the base down to the subgrade or subbase, and a short straightedge placed across the top of the hole. If the distance from the bottom of the straightedge to the top of the subgrade or subbase is more or less than the thickness shown on the Contract Drawings, the Contractor should be told to adjust the spreader to lay the right thickness. The change in depth of spread will have to be about 5/4 times the desired change in thickness of compacted base. For instance, suppose that the compacted thickness of base is to be 6 inches and the thickness of the trial layer, after compaction to 100 percent of the laboratory maximum density, is only 5-1/2 inches, or 1/2 inch too small. For the next trial the spreader should be adjusted to increase the depth of spread by about 5/4 x 1/2, or 5/8 inch.

After the proper thickness of spread has been set by trial, the mixture for a Type DG base must be spread over the entire width of base in one pass by using two spreaders nearly side by side. The second spreader must follow far enough behind the first one not to interfere with its free operation. However, the material from the second spreader should be placed against the material already laid as soon as possible, so there will be a positive bond between the two lanes without the addition of more water. The second spreader should be kept crowded against the edge of the lane already placed. If there are any gaps between the lanes, they must be filled by placing extra material taken with hand shovels from the spreader hopper or from dumping boards. Material already spread must not be used to fill holes.

Compacting Mixture for Type DG (Dense Graded) Base

25. The material for a type DG base must be rolled until fully compacted as soon as possible after it has been spread. If it loses much moisture, it cannot be fully compacted. If any of the spread material becomes too dry, that part of the mixture should be sprinkled with water before it is rolled. The base material can be compacted more easily if the moisture content* is slightly above optimum*, rather than below optimum. Rolling should start at one edge of the lane, overlapping the shoulder, and progress toward the other edge.

The grade and cross section of the base should be checked before rolling is started or after the first pass of the roller. High places caused by too

much base material can be cut down later with a blade grader. Any material removed by blading should be wasted and should not be bladed into low spots. At any low place the mixture must be loosened with rakes to a depth of 4 inches, and more base material added.

A low place should not be corrected by cutting down the part of the base next to it, as the base will then be too thin.

To get good results, the base material must be compacted to 100 percent of laboratory maximum density*. On a large job it is to the Contractor's advantage to find the combination of moisture content and equipment that will compact the material fully with the least amount of rolling.

All types of rollers should be operated at a speed of less than 5 miles per hour. A roller must be reversed or turned carefully so as not to scuff up the surface of the base.

All rolling must be done so that the material is pushed down and does not move out from under the roller wheels. It may be necessary first to roll the base very slowly with a steel-wheeled roller to key the material and keep it from being shoved. A three-wheeled roller should be operated with the large wheels in front so that the material is "tucked under" those wheels instead of being pushed up by the small wheel.

Vibrating rollers do a good job when they are correctly adjusted. For each material there is a best speed (frequency)* of vibration, and a best amplitude*. It is to the Contractor's advantage to have the vibrating roller adjusted to give the best results with the material being used.

When heavy rubber-tired rollers are used, the weight of ballast and the tire pressure should be adjusted to give the highest contact pressure* (ground pressure) possible without making deep ruts or pushing the base material out from under the wheels. The contact pressure for any combination of ballast weight and tire pressure can be found from the roller manufacturer's chart. With a 7.50-15, 10-ply compactor tire, increasing the wheel load from 3000 to 6000 pounds increases the ground pressure beneath the tire by about 15 psi (pounds per square inch). Increasing the tire pressure from 70 to 90 psi increases the ground pressure by about 7 psi.

A Type DG base is very hard when fully compacted. It may be necessary to use a chisel and hammer to cut holes in such a base for density tests. The density of the base should be uniform from top to bottom. If the material at the bottom of a hole made for a density test can be dug out more easily than the material near the top, the base is being placed in layers that are too thick, or the compaction equipment is not doing a good job.

<u>Priming Type DG (Dense Graded) Base</u>

26. If traffic can be kept off a completed base of Type DG, it should be allowed to cure as long as possible before being primed. If the base must be opened to traffic or used for hauling, it should be kept moist by being wetted down until primed, in accordance with the Specifications.

Sometimes priming this type of base will make its surface fluff up and lose density. If this happens, the surface should be knit together again by rolling the base with a steel-wheeled roller as soon as the prime has cured enough not to be picked up by the roller wheels.

Materials for Soil-Cement Base Course

27. A soil-cement base is built of a mixture of portland cement and suitable soil. Water is added in the mixing process to enable the cement to bind the particles of soil together. When the cement sets, the mixture becomes stabilized. In some ways a soil-cement mixture is like portland cement concrete, but it is a different material and must be fully compacted to have its full strength.

The soil and cement may be mixed in place on the subgrade or subbase, or the materials may be mixed in a plant and hauled to the job. If soil found within the limits of the excavation is suitable, it may be used either alone or in combination with another soil. Sometimes it is necessary to obtain all the soil from outside the limits of the project.

A soil-cement base must be compacted to high density in order to be strong enough. It must be placed on a firm subgrade or subbase. At any soft or springy spot in the subgrade, the poor material must be dug out and replaced with good subgrade material that is then fully compacted. Drains must be put in to allow the escape of any water found in a cut section during excavation. Also, the moisture content of the base mixture must be near the optimum for compaction with the equipment used, and there must be enough passes of the rollers to compact the material fully.

The proportion of cement (cement factor) that will give a soil-cement mixture the strength needed for a good base depends on the type of soil, and is found by laboratory tests. It may take a month or more to complete these tests. To avoid delay, samples of the soil to be used must be obtained and sent to the Laboratory soon enough to permit the results of the tests to be known before construction of the base is to be started.

Most of the strength of a soil-cement base is provided by the mixture of cement and silt and clay (material passing a No. 200 sieve). During construction of the base, the proportion of cement to silt and clay must be kept as close as possible to the proportion fixed by the design tests. Wet sieve tests must be made to be sure that the percentages of material passing the No. 200 sieve and the No. 4 sieve are as close as possible to the values obtained for the soil used in the design tests. Since the amount of cement used per square yard of base is usually the same for the whole job, changes in the percentage of soil passing the No. 200 sieve will have a great effect on the strength of the base.

The amount of coarse aggregate (material retained on the No. 4 sieve) in the soil-cement mixture also has some effect on the strength of the base. If the construction material has less coarse aggregate in it than the sample used for the laboratory tests, the proportion of cement to material passing the No. 200 sieve will be too low and the base will not have full strength.

Selection of Soil

28. When a soil-cement base is to be used, the natural soil all along the project should be examined to see if it can be used in the base mixture without the addition of other soil, if other soil must be blended with it, or if it is unfit for use, and must be removed. The Inspector-in-Charge should arrange to have tests made on any doubtful material. Soil that is dark gray or black usually has acid in it from rotting leaves or roots, and this acid would interfere with the action of the cement in the soil cement mixture. If there is only a small amount of such soil, it should be dug out and thrown away. If there are large amounts of dark soil, samples should be sent to the Laboratory for tests.

When samples of different types of soil found on the project are sent to the Laboratory, information should be included to show the station numbers between which each type of soil is found. Construction costs can be kept down if the over-all cement content is as low as possible. It may be economical to replace a large amount of poor soil with better material and use less cement; but extra cement is sometimes used with poor soil for a short section of base. As far as possible, all vegetable matter (such as sod or roots) should be removed from soil before it is mixed with cement.

Preparation of Soil in Place

29. In order that the cement may bind the soil particles together, the soil must be finely pulverized and free from large lumps. For mixed-in-place construction, the soil is usually scarified with a blade grader or plowed, and the lumps are broken up with harrows or by running the mixing equipment over the loosened material several times. Where the soil is clayey, the lumps can be broken up more easily if water is added to the soil and time is allowed for it to soak in. After the soil has been loosened, its surface should be brought to grade and the depth of the loose layer checked. There must be enough loose soil at all points to produce a base having the thickness shown on the Contract Drawings after the cement is mixed with the soil and the mixture is compacted.

It usually takes about 8 inches of loose soil to make a soil-cement base with a compacted thickness of 6 inches. A better loose depth can be found by digging a hole in the layer of loose soil, measuring the thickness of the layer, placing several thicknesses of paper in the bottom of the hole to mark the lower surface of the base, refilling the hole with the loose material, and then rolling the layer around this place until the material is fully compacted. After being compacted, the material in the hole is dug out again, a straightedge is placed across the hole and the thickness of the layer is measured from the bottom of the straightedge to the paper. Any necessary adjustment should be made in the loose depth to get the desired compacted depth.

The loose soil should be brought to uniform thickness and proper grade on a compacted subgrade before any cement is spread. If loose soil has been bladed into low places to bring the subgrade surface up to grade, it may be necessary to blade the entire quantity of loose material required for the base to one side of the road, and then roll the exposed subgrade until it

is fully compacted. The loose material on the uncompacted side of the subgrade, down to the subgrade surface, can then be bladed over only the compacted subgrade, and the newly exposed subgrade compacted. Finally, the loose material can be bladed over the whole width of the road to the right depth.

Spreading Cement

30. The cement spreader should be adjusted to spread the required amount of cement for the specified thickness of compacted base. A weighed truckload of cement should spread, for example, about 5/8 inch of cement for a 6-inch compacted thickness of base. The rate at which cement has been applied should then be checked by the Inspector-in-Charge, or under his supervision. The check can be made like this. The length of lane covered by the cement should be measured, and the number of pounds of cement spread per foot of lane found. If the base is to be 6 inches thick after compaction and the width of lane is 10 feet, the volume of mixture in 1 foot of lane is 6/12 x 10 x 1, or 5 cubic feet. If the required cement content is 10 percent, by volume, each foot of lane should contain 0.5 cubic foot of cement. One 94-pound bag of cement is assumed to have a volume of 1 cubic foot. So, the required rate of spread of cement is 1/2 bag or 47 pounds per foot of lane, and the spreader should be adjusted to spread this amount. The actual amount spread can be compared with the right amount. If not enough cement was spread in the trial run, the balance can be taken from bags with shovels and spread onto the lane.

When the required amount of cement is specified by weight, the dry weight per cubic foot of the soil-cement mixture must be known. If the design calls for 8 percent of cement, by weight, and the dry weight per cubic foot of soil-cement mixture (found when the design tests were made) is 120 pounds per cubic foot, then the required weight of soil-cement mixture in 1 foot of lane 10 feet wide and 6 inches thick should be 6/12 x 10 x 1 x 120 or 600 pounds. The required amount of cement in this weight of mixture, or in 1 foot of the lane, would be 0.08 x 600 or 48 pounds.

On small jobs, where cement is to be spread from bags, the number of bags required for 100 feet of lane should be figured in advance. The bags can then be spotted on the roadway so that they are correctly spaced at about equal distances in all directions; half spaces should be left between the bags and the edges of the lane. After all the bags are spotted, each can be split across the center with a shovel, and the cement can be dumped and spread evenly with shovels.

Mixing Soil and Cement

31. In building a soil-cement base, the cement should be well mixed with the soil before the water is added. The purpose of this mixing operation is to distribute the cement evenly through the mixture so that cement balls will not be formed when water is applied. Lumps of soil must be broken up, and there must be the same amount of cement in the soil at different places in the lane and at the top and bottom of the layer. On the job, uniformity of the dry mixture can be judged best by its color. After the soil and cement have been mixed, holes should be dug through the loose material to

the subgrade to see if the color of the mixture is uniform for the entire depth of the layer, showing that there is the same amount of cement at the bottom of the layer as near the top. Rotary tillers and single-pass mixers must be set to reach to the bottom of the layer. Other types of mixing equipment, which do not turn the material over, may take many passes to get enough cement to the bottom of the layer and produce a uniform mixture.

Cement should not be spread for too great a distance at one time, as a sudden rain may make the moisture content too high for proper mixing or compaction. If it starts to rain, the Contractor may decide to mix in the cement that has been spread and compact all the mixed material. If the material is very wet, the Contractor may find it necessary to use light rollers or a lower tire pressure for the rubber-tired roller when compacting the over-wet material. Cores may be cut from that part of the base later to find out if it meets density and strength requirements.

Water should be added to the mixture of soil and cement gradually from spray bars or sprinklers, and it should be mixed in as soon as it is applied. The amount of water added at one time should never be enough to flood the surface and make the mixture muddy. The optimum amount of water for a soil-cement base depends on the type of soil, the cement content, and the kind of equipment used for compaction. With most types of compaction equipment the total amount of water used in the mixture usually should not be less than the optimum amount shown by the laboratory test, and should not be more than the optimum amount by more than 20 percent of the optimum. When vibrating rollers are approved and used for the compaction of a mixture containing sandy soil, the best moisture content is often a little below the laboratory optimum. Rubber-tired rollers also may work best when the moisture content is slightly less than the laboratory optimum.

When the soil-cement is mixed in a central batch plant or continuous plant, the water should be added by sprays after a short period of dry mixing. The addition of cement in a uniform manner must be checked carefully. Scales in a batch plant must be tested to make sure that they are accurate for the weight of cement used. When cement is proportioned by continuous flight augers or vane feeders in a continuous plant, the proportion of cement, by weight, must be checked frequently. This is necessary because the weight of a loose volume of cement is not constant. If soil and cement are fed on the same belt, a check can be made by stopping the belt, then removing the amount of material within a measured length and weighing after drying. This weight is recorded as W1.

The belt is then run with the cement feed cut off, stopped, and the soil from the same measured length removed, dried and weighed. This weight is recorded as W2. The dried weight of soil (W2) divided by the dried weight of mix (W1) should equal or be less than 100 minus the required percent of cement by weight. If 8 percent by weight is specified then

$$100 \times \frac{W2}{W1} = (100-8) = 92\%$$

If there is any doubt as to correct proportioning the laboratory should be asked to give directions for taking and shipping samples.

Truck loads of plant-mixed material should be covered with tarpaulins during the hauling to prevent surface drying.

The right moisture content can be judged roughly by picking out the stones over 1/4-inch in diameter in a handful of material, and squeezing the rest in the hand. This remaining material should make a firm cast that can be handled without breaking, but should not leave any moisture on the hand. Judgment can be improved by making this test, and then checking the result against the moisture content found by drying a sample of the complete mixture.

Compaction of Soil-Cement Base

32. One way of compacting a soil-cement base is to use sheeps-foot rollers to compact the lower part of the layer, and to follow them with steel-wheeled rollers to compact the top part and leave a smooth surface. However, it is not practical to use most types of sheeps-foot rollers for soil-cement shoulder construction since they may damage the pavement and there is usually not enough room for them to turn around. Another way is to use vibrating or rubber-tired rollers, if they are specified or approved. Vibrating rollers will give the best results if the amplitude* and speed of vibration (frequency*) are adjusted to be suitable for the material being compacted. Rubber-tired rollers will increase density faster if the weight of ballast and the tire pressure are adjusted to give a contact pressure* a little less than that which would make the material squeeze out from under the tires during rolling.

After the base material has been compacted at the proper moisture content, it should have uniform density from the top to the bottom of the layer. Since the density test shows only the average density, conditions in the hole left by removal of the density sample should be observed and recorded while the hole is being dug. If the material near the bottom of the hole is looser than that near the top, better compaction equipment or methods should be used.

After the base is fully compacted, it should be trimmed to grade, and its surface should be made slightly rough by being scarified lightly so that the asphalt surface mix will not slide on it. Too much blading will make the base thin, since all material loosened by blading must be moved off the road and should not be used to fill in low spots. Scarifying is best done with a nail drag that leaves scratches about 1/8 inch deep in the surface.

Curing Soil-Cement Base

33. If a soil-cement mixture is kept moist, it will keep on getting stronger for a long time. When this material is used for a base, it must be kept from drying out until it has become strong enough. A soil-cement base must be protected from freezing. At low temperatures it gains strength much more slowly than at moderate temperatures.

A soil-cement mixture shrinks more than does portland cement concrete. As it cures, it usually cracks. Shrinkage cracks do not make a soil-cement base weak, but they usually show up through the surface course laid on the base. If cracks appear in the surfacing, they have to be sealed as a maintenance operation. For this reason, there should be as few cracks as possible in a soil-cement base.

To keep down the number and size of shrinkage cracks, the surface of the base should not be allowed to dry out too quickly. A good method of curing the base is to apply a seal coat of bituminous material to the surface. This coat not only is a curing agent, but also acts as a priming coat for the bituminous surfacing course that is laid on the base. The surface of the base must be kept moist until the seal is put on. More water may have to be sprinkled on the base just before the seal coat is applied, because the action of the cement in combining with water in the soil-cement mixture may pull water away from the surface of the base. The number and size of cracks in the base can be kept small if the base is well wetted down right after being compacted, and the bituminous seal coat is put on as soon as the water sheen has disappeared from the surface of the base. The surface of the base must be wet enough, when the seal coat is sprayed on, to prevent the bituminous material from penetrating too far into the soil-cement mixture. The material for the seal coat must be sprayed on the base evenly so that there are no gaps, skips, or thin places through which moisture can be lost from the surface of the base.

Protection of Soil-Cement Base

34. A soil-cement mixture does not gain strength as fast as concrete does. It takes at least 7 days, and longer in cold weather, for a soil-cement base to become strong enough to carry heavy traffic without damage. If a portion of the base must be opened to traffic or if heavy construction equipment will travel on it, it must be protected by wooden planks or by a layer of crushed stone or other granular material, several inches thick, which will spread the wheel loads over a large area of the base. If a part of the base will even be walked on or be subjected to light traffic within 7 days after the seal coat has been applied, that part must be covered with a thin layer of sand to keep the bituminous material from being picked up or punctured. A soil-cement base must be prevented from freezing.

Joints in Soil-Cement Base

35. Joints are often the weakest parts of a soil-cement base. If a joint is not made right, the mixture may start to ravel there before the surface course has been put on. Trouble in the surface course usually starts over poor joints in the base. To make either a longitudinal* or transverse* joint so that it will have the same strength and density as the rest of the base, the edge or end of a lane must always be cut back to solid material before new material is placed against it.

When a longitudinal joint is to be made with plant-mixed material, the edge of the completed lane should be trimmed back with the end of a grader blade to fully compacted material. When a mixed-in-place method is used, the loose soil for the new lane should be mixed with cement, and the mixture then bladed away from the edge of the lane of hardened material. The end of the grader blade should cut back to fully compacted material in the old lane. The new material can then be bladed against the joint.

When a plant-mixed material is used, a bulkhead may be set at a transverse joint in a soil-cement base. When the base is constructed by a mixed-in-place method, it is usually more practical to cut back the end of the lane to material that is fully compacted and that has the right grade and cross section.

New material next to the joint should be pulled away a short distance by a grader and then graded back, to make sure that the base mixture at the joint has the right amount of cement in it.

Soil-Lime-Pozzolan Base Course

36. A base may be built by mixing hydrated lime and flyash with the soil. The lime acts on the soil to lessen the effect of water on it. The lime also combines very slowly with the flyash to make a cementing material, somewhat like portland cement, which holds the soil particles together and gives strength to the base.

Construction and inspection methods for a soil-lime-pozzolan base are nearly the same as those for a soil-cement base. Dust often makes trouble when this type of base is being built and may be the cause of complaints from people who live near the road. If any wind is blowing, and the amount of dust must be kept to a minimum, it may be necessary to wet down the lime or flyash by sprinkling it with water by using a hand spray on a distributor running alongside the spreader or by operating a sprinkler just behind the spreader.

Both hydrated lime (which weighs about 45 pounds per cubic foot) and flyash (which weights about 70 pounds per cubic foot) are much lighter than portland cement (weighing 94 pounds per cubic foot). So the thickness of a layer of a soil-lime-pozzolan mixture for trial spreading should be greater than that of a layer of a soil-cement mixture. If the dry weight of the soil in the base mixture is 120 pounds per cubic foot, and the laboratory tests show that 9 percent of lime and 15 percent of flyash, by dry weight of soil, are required, the trial thicknesses of spread for a 6-inch compacted base would be about as follows:

Lime . . . . $\frac{120}{45} \times 0.09 \times 6 = 1.44$ inches,

or about 1-1/2 inches

Flyash . . . . . . $\frac{120}{70} \times 0.15 \times 6 = 1.54$ inches,

or about 1-5/8 inches

A soil-lime-pozzolan mixture gains strength much more slowly than does a soil-cement mixture, and should be kept moist and protected from freezing and heavy loads for a longer time. Because of the slow set, mixed material that is too wet to be compacted can be turned over and dried out. Also, compacted base that does not have a high enough density, or if too thin, can be scarified, reworked, and recompacted.

Materials for Soil-Bituminous Base Course

37. In a base built of soil mixed with asphalt or tar, the purpose of the bituminous material is to waterproof the soil and bind the soil particles together, after the mixture has been compacted. In general, the methods of preparing, mixing, inspecting, and compacting a soil-bituminous base are the same as those for a soil-cement base. The asphalt cement or tar is usually

thinned with a solvent (kerosene for asphalts) in a cutback or with water in an emulsion. The bituminous material most used is a medium-curing asphalt cut-back of type MC-2. Sometimes it is better to use type MC-3, which has less kerosene in it and is a little heavier or thicker.

The soil must be moist when the bituminous material is mixed with it. If the soil has the right moisture content, the bituminous material will spread over the surfaces of the moist soil particles and form a coating that will waterproof them. If the soil is so dry that the bituminous material soaks into the soil particles, it will not be easy to compact the soil mixture. If the soil is very wet, the contractor may prefer to use an asphalt emulsion such as F-4, or an inverted emulsion such as CE-1, or CE-3.

Amount of Bituminous Material

38. The amount of bituminous material required in a soil-bituminous base is found by laboratory test. It depends mostly on the proportion of the soil that can be washed through a No. 200 sieve. In order that all material passing a No. 200 sieve will be shown in the test, samples of soil taken during construction must include any clay lumps. The soil must be handled and blended so that the percent passing the No. 200 sieve in the material used in construction will be as close as possible to the percent passing in the sample used in the laboratory for the design of the mix.

The exact amount of bituminous material required in the mixture, as found by the laboratory test, is usually specified as a percentage of the weight of dry soil in the mixture. To figure the right amount to use on the job, the weight of dry soil in the compacted base must be known. This dry weight is found by subtracting the weight of the bituminous material, and the weight of the water in the mixture, from the weight of one cubic foot of mixture compacted to maximum density at the optimum liquid content. This weight of dry soil per cubic foot of mixture will be shown on the laboratory design report.

Assume that the weight of dry soil per cubic foot of mixture is 120 pounds, and the laboratory design calls for 6 percent MC-2 by weight of dry soil. Then the required weight of MC-2 per cubic foot of mixture is 120 x 0.06=7.20 lbs.

If the base has a compacted thickness of 6 inches and is built in lanes 12 feet wide, the volume of each foot of lane is 6/12 x 12/1 = 6 cubic feet. The weight of MC-2 required per foot of lane is 7.20 x 6 = 43.2 pounds.

The weight of all the MC-2 actually used, as shown by the delivery tickets, divided by the number of feet of lane placed, should be within 10 percent of the required amount per foot of lane. At the specified mixing temperatures, MC-2 or MC-3 weighs about 7.8 pounds per gallon. So, the volume of bituminous material per foot of lane for the assumed conditions should be about 43.2/7.8 = 5.5 gallons. This amount of material must be added gradually to the soil by giving the lane many light shots (applications) and mixing each one in before the next shot is put on. The Specifications limit any one application to 0.5 gallon per square yard. Since, in the assumed example, each foot of lane has a surface area of 12 square feet of 1-1/3 square yards, the most MC-2 that can be put on at one time is 1-1/3 x 0.5 = 0.67 gallon per foot of lane. This means that it will take 5.5/0.67 = 8 shots to put on the required amount of MC-2.

Mixing Soil and Bituminous Material

39. During construction of a soil-bituminous base, frequent checks should be made to be sure that the asphalt is being mixed with the material at the bottom of the layer. Also, when construction is started, a small area of the mixed material should be compacted and the thickness of the compacted material measured, to make sure that there will be enough mixed material to provide a compacted base of the required thickness. After the check is made, the compacted material should be broken up and mixed in with the rest of the material.

When the material is thoroughly mixed, it will have the same color at all places on the surface and at the top and bottom of the mixed layer. Mixing is usually easier at a moisture content above the optimum. If the soil balls up during mixing, it may be necessary to add a little more water. Only a small amount should be added, as the volatiles (solvent) and most of the water must be evaporated from the bituminous material before the mixture is compacted. The mixing must distribute the asphalt uniformly. If there is not enough asphalt at any place, that part of the base will soften, after compaction, when it gets wet. If there is too much asphalt at any place, it will be hard to compact that part of the base to high density.

When the Soil-Bituminous Base material is mixed in a central batch or continuous plant the moisture content of the soil, before mixing, should be controlled if the soil is dry. Water should be added uniformly by means of sprays. After mixing the material should have a uniform, dull black, color. If the mix has a brownish appearance it probably does not contain enough asphalt. In this case, the laboratory should be asked for directions as to how samples should be taken and sent in.

Curing Soil-Bituminous Mixture

40. After the material is completely mixed, it must be cured before it is compacted. As much as possible of the kerosene or other solvent must be evaporated, and the moisture content brought to the optimum for the material and compaction equipment. A soil-bituminous base cures very slowly after it has been compacted. If it is compacted when it has too much water or solvent in it, it will be soft and weak. It will stay this way a long time, except for a thin crust on top, unless it is plowed up, remixed, and dried some more, and then recompacted.

Good drying weather is absolutely necessary for proper curing of the mixture. On the approach of rain, the Contractor may decide to windrow the mixture. On a small job it may be possible to protect the windrow from rain with tarpaulins or plastic sheets. If the material has been spread and then gets too wet, it should be left in the spread condition until most of the extra moisture has disappeared. When the material is very wet, continued mixing in an effort to dry it out thins down the asphalt coating on the soil particles, with the result that the compacted base will not be so waterproof as it should be.

Material that has been wetted by rain, but is not too wet, should be windrowed. When curing conditions are favorable, material should be cut from

the windrow and spread over the subgrade with a grader in a layer about 2 inches thick. The base mixture will dry and cure much faster in thin layers. It is also easier to compact a thin layer to high density.

Compaction of Soil-Bituminous Base

41. When a soil-bituminous base is compacted in thin layers, the surface of each layer must be lightly scarified or roughened with a nail drag so that the layers will bond together. With this type of base there is sometimes trouble with lamination; that is, the top part of the base starts to slide over the lower part during compaction. When this happens, the whole base should be plowed, remixed, and recompacted. When the base is built in layers, roughening the surface of each layer helps to keep the base from laminating.

It is very important that the mixed material be cured and at the right moisture content when it is compacted. In general, most of the kerosene or other solvent should have evaporated. Compaction at a moisture content below optimum makes the strongest base, but it is hard to compact the material to the required density. It is best to compact the layer when the mixture is as dry as possible and still can be fully compacted with the rollers used on the job.

When the mixture is cured out to the point that it is ready for compaction, the asphalt will be stuck firmly to the soil particles. When squeezed in the hand the mixture should make a firm cast. When a small amount of the mixture is held in the palm of one hand and mixed and rubbed with the ball of the thumb of the other hand, neither the hand or the thumb should become blackened with asphalt.

If the Contractor uses heavy, rubber-tired rollers for compaction, the weight of ballast and the tire pressure should be adjusted so that the tires do not make ruts in the base material after the first few passes. On the final rolling the rubber tires should leave shallow grooves in the surface of the base that can be smoothed out by rolling with a heavy, steel-wheeled, tandem roller.

The base should be allowed to cure as long as possible before the seal coat is put on. The base material cures very slowly after it has been compacted; but the more kerosene or other solvent that evaporates from the base after compaction, and the drier the base is, the stronger it will be.

CHECK LIST OF IMPORTANT ITEMS

BASE COURSE CONSTRUCTION

Has all necessary drainage and underground work been completed? Has location of subgrade drains been recorded and outlets marked with stakes?

Has subgrade or subbase been checked for soft spots, or areas that will yield under the roller?

Has subgrade or subbase been checked for proper grade and cross-section by actual measurement from grade stakes? Are there enough stakes?

Has subgrade or subbase been checked to make sure that it has not lost density and is ready for base?

Have shoulders been constructed to the lines and grades shown on the drawings? Fully compacted? Have enough drains been installed through the shoulders to prevent flooding in case of heavy rain?

Have all manholes, valve boxes or other embedded items been installed and checked for exact grade?

Have all materials the contractor intends to use been tested and approved?

Does the contractor have enough equipment on the job? Is it the right equipment for constructing the type of base specified? Has the equipment been approved by Laboratory (if required)? Are there enough straightedges and crown boards (if required) on hand?

Does everyone understand exactly how the base must be built to meet Specification requirements? Have the Special Provisions been checked?

Have arrangements been made for continual tests during construction?

Has the adjustment of equipment been checked to make sure that the base constructed with it will have the specified thickness at all points?

Has blanket course (if required) been checked for uniform thickness? Have all dirtied or rutted areas been corrected?

Has the rolling of stone for base been checked to make sure there are no soft places in the subgrade or subbase? Have these areas been corrected?

Has stone been checked to make sure it is not breaking under roller because of overrolling or because of soft stone not meeting Specification requirements?

Are screenings for base (crushed stone) dry or are they being spread thinly and dried? Is enough brooming being done to distribute screenings evenly?

If vibrator is being used to vibrate screenings into stone for a crushed stone base, is it being checked constantly to make sure that stone is not being floated?

Does grout on surface of crushed stone base set up hard and lock the stone into place after drying? Does inspection of completed base after rain show open areas that indicate that choking and grouting was not properly done?

Has all crushed stone base been straightedged after completion to make sure that it meets Specification requirements?

Have the required number of base thickness tests been made and does the base meet the thickness requirements?

Have precautions been taken to protect completed crushed stone base from traffic?

Has amount of prime actually applied for AP base been checked and recorded?

Has grade and crown of second course AP base been checked before bituminous material is ordered?

Has rate of application of bituminous material been checked?

Has density and thickness of Type DG base been checked? Does material in-place meet gradation requirements?

Has thickness and density of soil-cement been checked? Does density and cement content of the base meet Specifications, especially at the bottom of the base?

Have arrangements been made to keep soil-cement base moist until seal coat is applied?

Has soil-bituminous base been cured to proper content before compaction?

Has thickness and density of soil-bituminous base been checked? Does density and bitumen content of base meet specifications, especially at bottom of the base?

CHAPTER VII

REINFORCED CEMENT CONCRETE PAVEMENT

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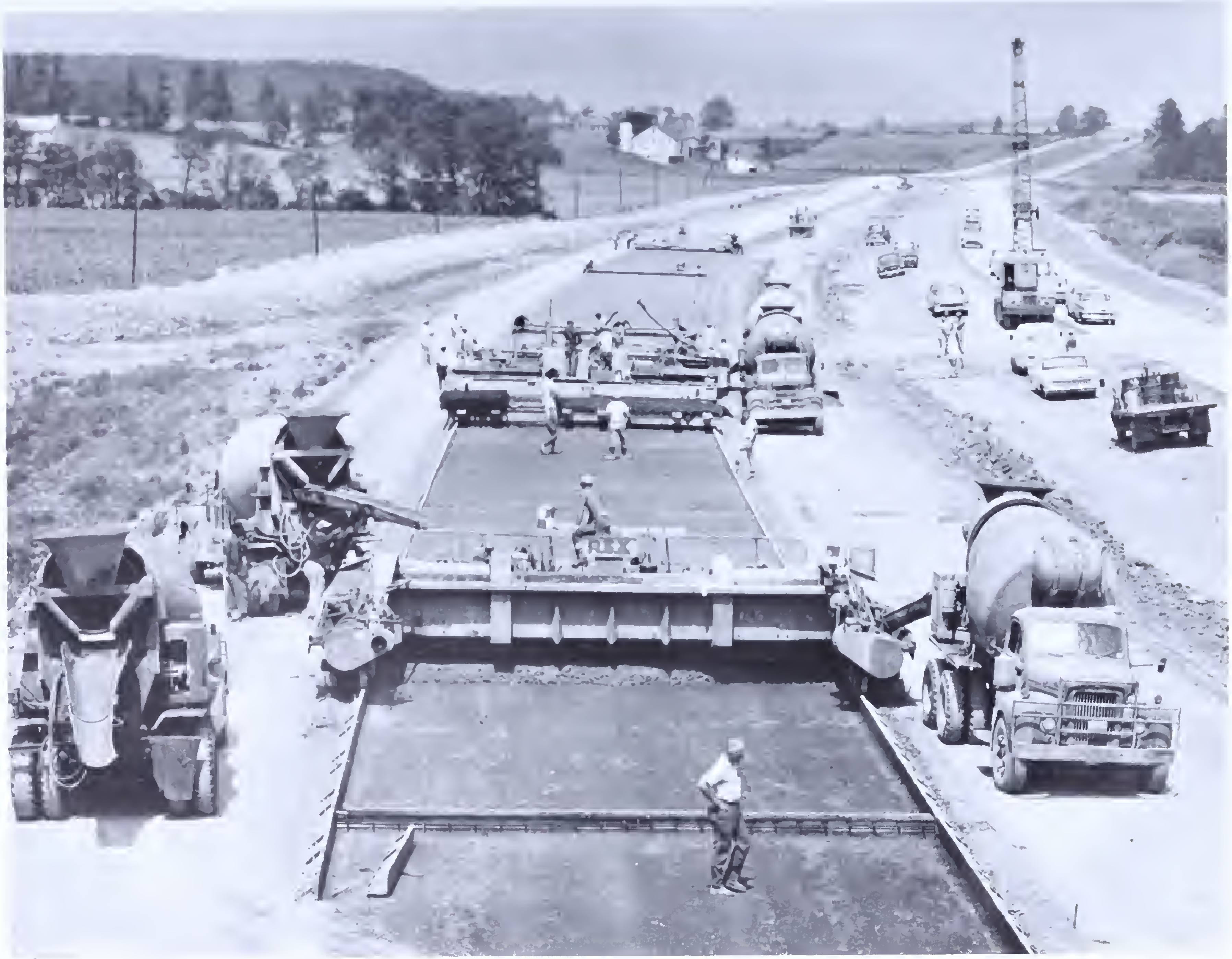
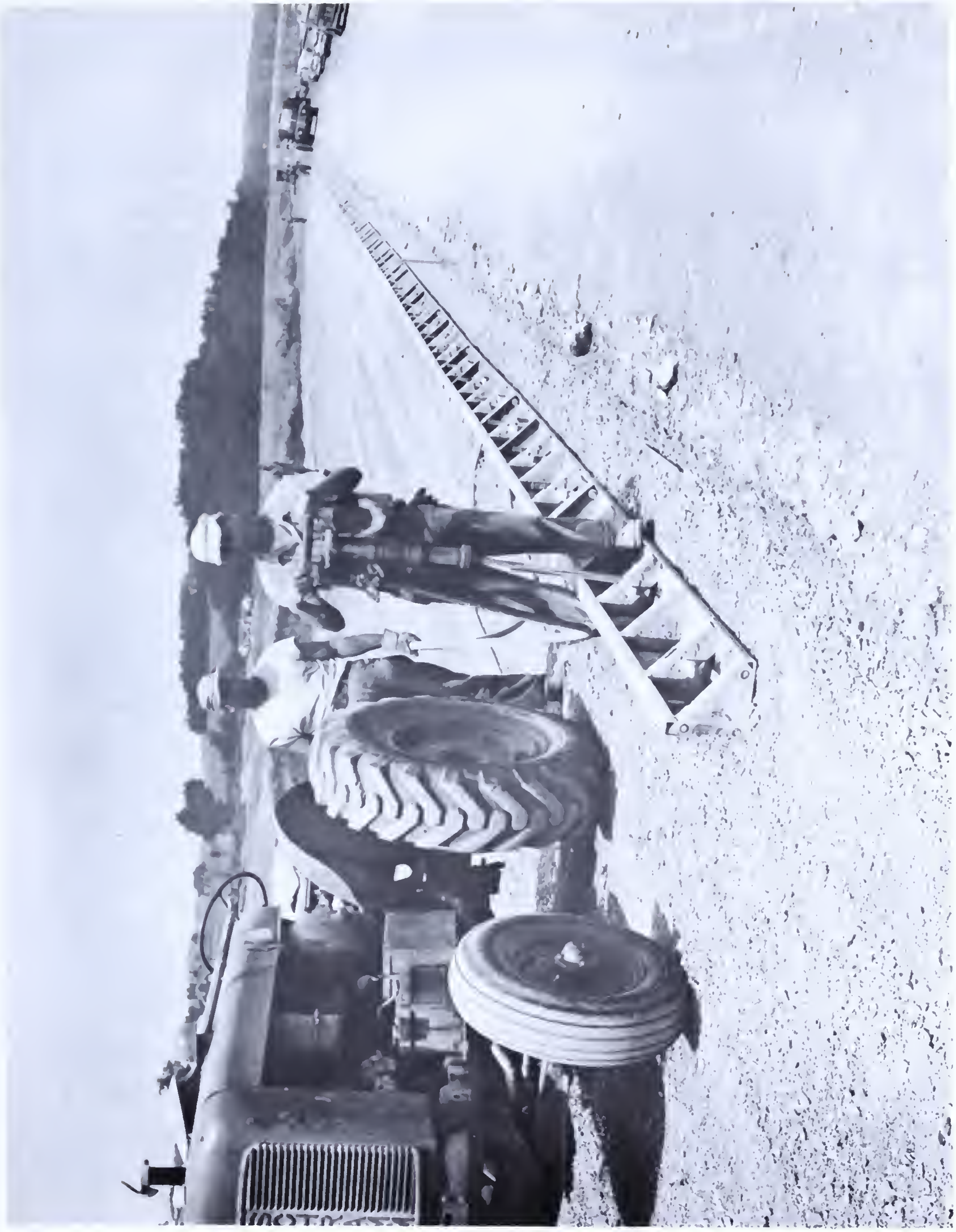


Reinforced Cement Concrete Paving



Setting Form Pins

CHAPTER VII

REINFORCED CEMENT CONCRETE PAVEMENT

General Requirements

1. Concrete pavement should have a smooth riding surface, should look good, and should last a long time. Its riding qualities and appearance show how well the Inspectors did their work. If the concrete cracks or if pieces chip out of the surface soon after the work is finished, the Inspectors may not have been careful enough in doing their work.

A nearly perfect concrete pavement can be built if the Inspectors know what has to be done and see to it that every operation is done correctly. The purpose of this Chapter is to point out the details that have to be watched to get a good job and to tell how the work should be done. The Specifications* help give the Inspector the backing he needs to have the Contractor do the job properly. Before any part of the work is started the Inspector should study the sections of the Specifications which show what the Contractor must do. The Inspector must make sure that he understands them and that the Contractor's men do, too. If there is any doubt or disagreement the Inspector-in-Charge should be asked to make clear just what is to be done. THE INSPECTORS SHOULD ALSO READ THE PROPOSAL AS WELL AS STUDY THE DETAILS AND NOTES ON THE DRAWINGS AND NOTE IF THERE ARE ANY SPECIAL PROVISIONS OR NOTES WHICH APPLY TO THE WORK BEING DONE.

Steps in Pavement Construction

2. Before the concrete in a pavement can be placed, it is necessary to prepare the subgrade* (including drainage*), build the subbase*, set side forms, and put steel dowels in position at joints. The concrete is mixed in a paver on the job, at a central plant, or in a truck mixer. While the concrete is being placed, joints* must be formed and the steel reinforcement put in the pavement. After the concrete has been placed and its surface shaped, it must be cured and protected from damage for a period of time. Before the highway is opened to traffic the joints* must be sealed.

Methods and Practices

3. Many years of experience in building concrete pavements show that certain methods and practices must be followed to produce a good pavement. A good pavement meets all of the requirements of the Specifications. Also it will please the people who travel on it. They enjoy

NOTE: Words marked with an (*) are explained in the word list at the back of this book.

a smooth ride and like to see straight joints. Finally, a good pavement will last a long time without a lot of maintenance. Some of the things that are important in order to get a good pavement are:

(a) Good drainage of the subgrade, subbase, and the pavement surface.
(b) Fully-compacted fills (embankments) built on stable ground.
(c) Subgrade and subbase prepared and compacted* true to the required cross section.
(d) Materials used in the construction of the pavement such as cement*, fine and coarse aggregates*, water, reinforcing steel*, graphite lubricants*, joint sealers*, curing material* and assemblies for expansion and construction joints* obtained from approved sources of supply and tested and approved by the Engineer of Tests before they are used.
(e) Aggregates that are free from foreign materials, and accurately proportioned.
(f) Department procedures followed in the sampling and testing of materials during the progress of the work.
(g) Correct design of the concrete.
(h) Full cement content in each batch of concrete mixed and the correct amount of water used in mixing it.
(i) An approved mixer which has an accurate timing device and a bell, or a system of colored lights, and a way of locking the discharge lever during the mixing period.
(j) Full mixing time after all materials for a batch* are in the drum of the mixer.
(k) Forms that meet Specification requirements and are staked accurately to line and grade, with all precautions taken to prevent them from settling.
(l) Transverse joints in the required locations and staked accurately and securely so that each joint will be in a straight line at right angles to the centerline, or as required, and also perpendicular to the surface of the pavement; particular attention should be given to the elevation and alignment of the dowels*.
(m) The doweled keyway* in the longitudinal joint installed in accordance with the Standard Drawings and securely fastened against the form to prevent its movement during vibration of the concrete.
(n) The subgrade or subbase kept well moistened ahead of placing of the concrete.
(o) Reinforcement accurately placed to have the final position as shown on the Drawings.
(p) Thorough spading* of the concrete to its full depth along forms and down to the reinforcement at all joints, and compaction of the concrete below the reinforcement at all joints with an approved vibrator.
(q) Finishing the concrete surface at the proper time with the right tools. Complete checking of all parts of the surface

with accurate straightedges while the concrete is still plastic*, to make sure the surface is smooth.

(r) Not too much working of concrete during finishing. No late edging of joints and sides, especially after the concrete has taken its initial set*.

(s) Curing begun as soon as the concrete has been finished and is hard enough not to be marred by the curing material.

(t) Inspection of slab edges as soon as the forms are stripped*, and prompt repair of honeycomb. Taking action to prevent poor results from occurring again.

(u) Protecting pavement from all traffic during the full curing period and until the joints are sealed.

(v) Cleaning and sealing joints and cracks, correcting of surface irregularities as required, and constructing shoulders for edge protection before traffic is allowed to use the road.

Only the most important points of concrete pavement construction have been listed. Each operation includes a large number of small steps. The Inspector must check every detail of the work because each step must be done right to get a good pavement. He must be on the job constantly and see to it that every part of the work is done in the right way and at the right time.

THE QUALITY OF THE PAVEMENT DEPENDS LARGELY ON THE AMOUNT OF ATTENTION THE INSPECTOR PAYS TO THE DETAILS OF THE WORK.

Duties of Inspector-in-Charge

4. The first duty of the Inspector-in-Charge on a concrete paving job is to be completely familiar with all details of construction and plant inspection. He must instruct his assistants, explain their duties and show them how to do each thing. He must also check their work often to see that they are on the job and are performing their duties. The Inspector-in-Charge is responsible for both the performance and the quality of the inspection done by the men under him.

The Inspector-in-Charge must also see to it that the Contractor makes arrangements for getting the work done according to the Specifications. He should make sure that the Contractor plans to use enough men, that the men in charge of the work know how to run the job, and that the Contractor's equipment meets Department* requirements. In the presence of the Mixer Inspector and the Contractor or his representative, he must have the equipment tested as required by the Department.

Before a trial mix* is set up for the concrete to be used on the project, the Inspector-in-Charge must see to it that the materials used in the trial mix are representative of the sources of supply for the pavement. He should make sure that enough material from each source has been tested, approved, and placed in storage.

Before paving is started, the Inspector-in-Charge should discuss the entire paving operation with the Contractor's paving superintendent and the concrete foreman in the presence of the Mixer Inspector. Everyone should understand the Department requirements, so that there will be no disputes and delays after work has begun.

Properties of Concrete

5. Concrete for a pavement is usually a mixture of portland cement, water, fine aggregate, coarse aggregate, and an agent for entraining additional air. In cold weather, calcium chloride may be added to make the concrete set more quickly. The cement may be normal portland cement* or high-early-strength cement*. The water must be tested and approved before it is used in the concrete mixture. The fine aggregate is usually well-graded sand; the coarse aggregate may be gravel, crushed stone, or crushed slag from a blast furnace. The air-entraining agent* is put in the cement at the mill. If tests show that it is necessary, additional air-entraining agents may be added at the mixer by an approved method.

Usually the cement and aggregates are measured by weight at a batch plant located some distance from the job and hauled to the job in trucks. They are then placed in a mixer (paver) and the freshly mixed concrete placed in the forms by a bucket which travels along a boom attached to the mixer. In some cases, the cement and aggregates for a batch of concrete are measured by weight at a plant and put in a mixer mounted on a truck; water is added from a tank on the mixer and the concrete is mixed after the truck reaches the job. When special permission is obtained the concrete may be mixed while the truck mixer travels from the plant to the job. Another method is to weigh out and mix all materials for a batch of concrete at a plant, then haul the mixed batch to the job in a truck mixer or a truck with a special body. Concrete mixed at a plant and shipped to the job in an approved type agitator, or delivered to the job by a truck mixer, is known as ready-mixed concrete.

When first mixed, concrete must be plastic enough, within the Specification limits, to be placed in the forms. As time passes, the cement "sets"* and the concrete hardens. The strength of concrete increases with its age, and well-made concrete becomes strong and dense. The final strength of concrete depends mainly on the "water-cement ratio", which is the number of gallons of water used for each bag, or sack, of cement. In general the lower the water-cement ratio, the greater will be the strength of the concrete.

Design of Concrete Mix

6. Designing a concrete mix means choosing the amounts of cement, water, fine aggregate, and coarse aggregate to be used in one batch. The concrete must meet Specification requirements and be workable so that it is easy to place and finish.

The Contractor is required by the Specifications to work out a trial design for the concrete mixture in accordance with Department Bulletin No. 5. At least one week in advance he must arrange to have the Assistant District Construction Engineer present while the trial design is prepared. All work on the design must be done in the presence of the Assistant District Construction Engineer and the Inspector-in-Charge on the project. When they are satisfied with the mix design it must be sent to the District Engineer for approval. After the design has been approved the Contractor must not make any changes in it without the consent of the District Engineer.

Contractor's Paving Personnel and Equipment

7. The Contractor must have a well organized working force of capable men. According to the Specifications the Contractor must have on the project at all times a competent Superintendent, or other representative, with full authority to receive and carry out orders from the Inspector-in-Charge and to make arrangements for any materials, equipment or labor that may be needed. The Contractor must also hire capable workmen. If any man is not fitted to do his job, or will not follow instructions, the District Engineer, or his representative, has the authority to have him discharged.

The Inspector usually has to see how the men work before he can judge if they are competent, but before the job is started he can at least make sure that there are enough men to handle all the details of the paving work. It is important that there be enough men and finishers* to install and finish the joints as well as enough labor to handle the protection and curing of newly-laid pavement in accordance with the Specifications. As the work progresses the Inspector-in-Charge should let the Superintendent know about any workmen who are not doing a good job. If their workmanship does not improve, the Inspector-in-Charge should see to it that they are replaced.

Inspection of Paver

8. All equipment that is needed for paving must be on the job and be inspected before the work is started. Requirements for concrete mixers are given in the Specifications. Whenever possible, the mixer to be used on the project should be inspected by the Inspector-in-Charge, the Assistant District Construction Engineer, and the District Construction Engineer, to make sure it is in good mechanical condition and meets Specification requirements. After the paving has started, operation of the mixer must be checked at least twice daily by the Mixer Inspector.

The initial inspection of the mixer will include a check of the rating plate, the mixer blades, the timing device, the speed of the drum, the water measuring equipment, the dispenser for the air-entraining agent (when required), the loading skip, the bucket, and the splash pan.

Before starting work the Mixer Inspector should try to get from the Contractor a copy of the manufacturer's Specifications for the mixer that is to be used. The mixer blades must be measured accurately and blades that are worn down more than 3/4 inch in any place must be replaced before the mixer is used. While the blades are being checked for wear, the drum should be checked to make sure that it is clean and that no hardened concrete has stuck to the drum or built up between the blades and the drum.

The timing device must be checked to make sure it is set for the mixing time required by the Specifications and that the bell or system of colored lights which shows the release of the locking device is working. Mixing time is measured from the time all materials are in the drum. For the initial check of the timing device the time may be measured from the time the raised skip hits the drum and starts the timer to the time the locking device is released.

The mixer drum on a paver should make between 14 and 20 revolutions per minute (usually a rate of 17 rpm is set for paving work). This can be checked by making a kiel* mark on the side or end of the drum and counting the number of revolutions in 60 seconds. Any watch that has a second hand may be used for this purpose.

The water pump on the mixer should be operated, and the lines and valves inspected, to make sure that no water will leak into the drum. If there are no leaks, the water tank should be filled so that the reading on the gage, in gallons, is about the same as it will be during average operation of the mixer. Since water weighs 8.33 pounds per gallon, the weight of the water in the tank should be 8.33 times the gage reading. A platform scale is then leveled up on a temporary platform near the water tank and this scale is checked for accuracy. After the scale has been adjusted, a 50 gallon steel drum is placed on the scale and its weight recorded. The mixer tank is then filled with water in the required increments and discharged through a bypass into the drum and the drum and its contents weighed. The weight of the water is found by subtracting the weight of the drum from the final weight. The weight of the water from the tank should be within one percent of the number of pounds found by multiplying the gage reading by 8.33. For example, if the gage on the water tank read 36 gallons, the increase of weight of the measuring drum should be 36 x 8.33 or 300 pounds, plus or minus one percent, or between 297 and 303 pounds. This test must be repeated with the water tank filled to gage readings 5 and 10 gallons above and below the average gage reading to cover the whole range of gallonage that may be required by different moisture contents of the aggregate. At least 4 tests must be made and the results of each test recorded.

When an approved dispensing device is used on the mixer to supply additional air-entraining agent (used when ground-in agent in cement does not entrain enough air in the concrete), it must also be tested. The supply drum should have a gage that will show the amount of agent on hand at any time. Transparent plastic tubing should be used to connect the supply drum to the dispensing device in order that the movement of the agent in the tubing may be seen when the dispenser is operated by the raised skip. To check the setting of the dispenser it should be operated by hand; the full amount of agent discharged should be first caught in a small can, then poured into a bottle with ounce graduations, or some other measure, to check the quantity.

During paving operations the supply of air-entraining agent should be checked often to make sure that the supply drum contains enough to allow the dispenser to work. The dispenser should be checked for positive action by watching the movement of the agent in the tubing.

The cables on the loading skip should be inspected to make sure that they are not worn or frayed. Cables in poor condition are dangerous as they may break and let the skip drop suddenly. The skip should be checked to make sure that none of the material for a full batch will spill out before it is dumped into the mixer drum. The inside of the skip must be clean and smooth so that all of the batch will slide easily into the mixer drum when the skip is raised. If the mixer is to be operated on concrete pavement, provision must be made for protecting the pavement from the paver treads and the bottom of the skip must have a bumper block, such as an old auto tire, to protect the pavement when the skip is dropped. Because many Inspectors and workmen have been killed by mixer skips <u>EVERY MIXER IN OPERATION MUST HAVE BARS THAT WILL PREVENT ANYONE FROM WALKING UNDER THE RAISED SKIP.</u>

<u>Inspection of Bucket</u>

9. The bucket should be inspected to see that the movable bottom closes tightly and that mortar will not leak out when the bucket is filled with concrete.

The mixer must have a splash pan to catch any mortar that leaks or spills from the mixer.

<u>Inspection of Concrete Spreader</u>

10. The concrete spreader which will spread the concrete between the forms should be inspected to make sure that the gages which show the elevations of the spreading device and the strike-off read zero when the lower edge of the strike-off plate immediately behind the spreading device is at the level of the top of the forms. This can be checked by means of a wire stretched across the tops of opposite forms.

During paving operations the control for the strike-off plate should be set to the right elevation and then the control of the spreading device (screw or plow) should be set about one inch higher for a first trial. The spreading device should leave enough concrete so that the strike-off plate will always carry some concrete in front of it but will not be overloaded.

Inspection of Transverse Screed

11. The transverse screed* should be checked for straightness (or specified crown when shown on the plans) and for tilt. A method of checking is to stretch two wires across the tops of opposite forms at a distance apart equal to the width of the screed. The screed can be lowered onto small wood blocks of equal height placed on top of the forms. By measuring from the wire to the front and rear of the screed at several points, both the straightness and tilt can be checked. The tilt of the front screed that will give the best results must be found by trial after paving has started. For air-entrained concrete, a good initial setting is to have the front screed tilted so that the front, or leading, edge is about 1/8 inch higher than the rear edge. The rear screed should usually have very little tilt or none at all. The screeds rest on wearing plates which ride on the forms. These plates should be checked for signs of excessive wear. The double flanged wheels which will be used on the machine for riding forms and the rubber-tired wheels used for riding pavement should be checked to make sure that they conform to the requirements of the Specifications.

Inspection of Longitudinal Finisher*

12. Any ridges or waves left in the pavement by the transverse screed should be removed by a longitudinal finisher. The finishing float is attached to a frame mounted on wheels and moves across the pavement on tracks. The wheels on one side must have double flanges. Specifications permit the use of steel wheels without flanges on the other side, provided that the joints in the pavement are protected. However, rubber-tired wheels generally are preferred.

The longitudinal finisher should be inspected very carefully, because its use should practically complete the finishing of the pavement surface. The manufacturer's instructions should be consulted when checking adjustments, but if they are not available, the first step is to stretch a wire across the top of the forms and, by measuring to the flat track, make sure that it is perfectly straight. In the few cases where a curved track is used, the District Office will furnish the measurements for checking it. Checking should be done while the operator is standing on the operating platform.

The next step is to check the bottom of the float with a straight edge. Two wires should then be stretched across the tops of opposite forms at a distance apart equal to the length of the float. When the float is in the lowered position all corners of the float should be the same

distance from the wires. The double flanged wheels to be used with this machine should be checked in the same way as for the transverse float.

A combination finisher, or sled float, if used instead of a longitudinal finisher, must also be inspected to make sure that it will produce a finished surface that is a true plane with respect to the tops of the forms. This type of finishing machine is not much affected by small form irregularities. This is because the transverse oscillating screeds and a stationary float are carried on a long wheel base frame. The first screed on this type of equipment is usually a conventional transverse screed and is checked by the procedure outlined above. The second screed and float do not ride on the forms but are suspended from the frame. For this reason the second screed and the float must be checked to see that they are set in the down position at about the elevation of the top of the forms. Also that no finishing surfaces are warped. The method of checking is the same as for the longitudinal float. Wires must be stretched across the forms, and measurements taken to the flat finishing surface and trailing edge of the float, and to the corners of the finishing surface in the case of the screed. Small final adjustments are made after the start of the work to get exactly the right cross-section and finish of the pavement surface.

Inspection of Subgrade Tester

13. A subgrade tester is used for checking the grade of the subbase just before the concrete is placed. It should be checked for conformance with Department Standards. The sharp pointed spikes should be six inches apart and must have a means of adjustment and means for locking the adjustment. The spikes must be checked for length by the directed method. One way to check is to place the tester on the forms (or on sections of form at least five feet long). A piece of angle iron that has been checked for trueness, by means of a straightedge or a stringline, is placed on the subbase between the forms and at right angles to them. This angle iron is adjusted so that the distance at any point from the tops of the forms to the top surface of the leg which lies flat on the subbase is exactly equal to the slab thickness. This distance is checked by measuring from a stringline or wire stretched across the tops of opposite forms. The subgrade tester is then rolled into position so that the points of the spikes are over the flat leg of the angle iron, and the length of each spike adjusted so that the points of the spikes are exactly 1/8 inch above the surface of the flat leg of the angle iron. (This 1/8 inch clearance is not a tolerance in pavement thickness. The completed slab must be the full thickness shown on the plans.) A distance of 1/8 inch can be measured by using a double thickness of the standard-issue 6-foot folding metal rule. After initial adjustment, the subgrade tester must be checked at least twice daily during construction.

Inspection of Forms

14. Each section of metal form must be inspected for conformance to the requirements of the Specifications. When checked with a straightedge both the face and the bottom of the form must be within 1/8 inch in 10 feet of a true plane. The wedges for each stake pocket and the locking devices at the end of the form must be in place, clean and in good condition.

Wood forms, which can be used only on sharp curves with a radius of less than 250 feet, must be made of two thicknesses of 1-inch seasoned and surfaced plank, rigidly fastened together and to the base 8 inches wide. The base must be drilled at least every 2 feet for form pins.

The Contractor must have enough forms on hand to set at least 750 feet in advance of paving on both sides for one-lane construction and at least 500 feet on both sides for full two-lane construction.

There should be on hand at least 3 form pins for each section of form. Form pins must be at least 7/8 inch in diameter and 30 inches long. If subbase and subgrade are such that 30-inch pins will not hold the forms securely, the Contractor must furnish longer pins. In rare cases, such as over rock, 30-inch pins cannot be fully driven and the tops of the pins would stick up above the top of the forms and would interfere with the operation of the equipment. In such cases pins shorter than 30 inches may be used, but only by special permission of the District Engineer.

Inspection of Vibrators

15. In addition to the vibrators* required for the vibration of concrete next to the forms and to the joints, a replacement vibrator must be on hand in case one of the others breaks down. The Inspector-in-Charge should not permit paving operations to start until he makes sure that this extra vibrator and other reserve equipment is ready for use. He should list all such extra equipment on the job in the diary for the project. The Contractor is required by the Specifications to furnish enough approved vibrators which have a specified rotational speed, or produce a specified number of impulses, when the spud* is buried in the concrete. A vibrator will usually give satisfactory results if it visibly affects the surface of the concrete (slick shiny appearance) for a distance of 18 inches in all directions when the spud is held vertically in the concrete for not more than 5 seconds.

Inspection of Batch Trucks

16. The Contractor should have enough batch trucks to keep the mixer busy so that there will not be any long waits between loads. Each batch truck must have partitions that will keep the batches entirely separated during hauling and dumping. A truck that has been working

under a shovel sometimes has the bottom of its body so dented that the partitions cannot fit tightly and some material will leak from one compartment into another during loading and dumping. Such a truck should not be used. Each partition must be high enough to prevent material from being spilled over it during dumping. Each partition must have a positive locking device to keep it from coming loose during dumping, so that only one batch will pass into the skip at a time. If two batches are dumped together there will be a delay, since the material must be discarded. If cement compartments are used, they must have water and dust tight covers. They must have positive locking devices on tightly closing bottoms so cement will not leak into the batch compartment during loading. The inside of a cement compartment must be free from caked cement and the design must be such that all the cement will always be discharged when the batch is dumped.

Inspection of Straightedges

17. The Contractor should have on hand at least 4 straightedges 10 to 16 feet long for use on the pavement, two 10-foot straightedges for checking forms and two 4-foot straightedges for checking joints. In addition to these, a master straightedge should be made for checking the straightedges used in the work. This can be a 3 x 12 inch hardwood plank 17 feet long with end supports like those of a carpenter's horse. When wooden straightedges are used, a wood plane should be kept at the master straightedge so that the working straightedges can be trued up.

There also should be two 16-foot straightedges for checking the surface of the pavement already constructed. These straightedges should never be used for any other purpose.

Inspection of Edgers

18. Four edgers* having a 3/4 inch radius for rounding top edges of sides of the pavement slab, and four having a 1/4 inch radius for rounding the edges of the joints, are needed. Two of each size should be kept in reserve. Edgers become worn through use and should be checked for proper radius. This checking is best done with a metal washer or other circular metal disk having a diameter twice the specified radius of the edgers (a diameter of 1/2 or 1-1/2 inches).

Miscellaneous Equipment and Hand Tools

19. The Contractor must furnish all the equipment, tools and material that it takes to do the work as required by the Specifications. There will be less delay and less unsatisfactory work if all equipment is on hand before the start of paving.

Pieces of equipment usually required are:

- 2 Foot bridges
- 1 Rolling finishing bridge (two if required by the rate of paving)
- 1 Hand screed or tamping template (two if hand finishing is necessary)

1 Finishing belt, two feet longer than the usual width of the slab, conforming to Specifications
1 Finishing belt, (usually a strip of burlap) two feet longer than the widest section of pavement, conforming to Specifications
8 Devices for installing side steel (if such steel is used)
1 Device for installing tie bars (for two-lane construction)
2 Joint straighteners
1 Standard lute*, conforming to Specifications (two if required by rate of paving)
1 Rack for holding burlap used for final belting
4 Brushes, or burlap, for finishing the concrete after edging
1 Carpenter's level for checking vertical alignment of forms and checking for form settlement
1 Hack saw
1 Heavy duty wire cutter
1 Large carpenter's square for setting bulkheads and expansion joints
4 Trowels for opening joints and sides
2 Wooden hand floats (no long handles)
3 Flags for marking ends of sections of pavement with different curing periods
1 Lock and key for mixer timer

The Contractor should also have on hand enough:

. Metal or wooden strips, 3/4 x 3/4 inches, for finishing expansion joints after the protective plate has been removed
. Guides for ends of transverse joints
. Bulkheads made of 3-inch wood, or 1/2-inch steel, or other approved design (minimum of two)
. Square pointed shovels and concrete spades
. Hose for sprinkling subbase and wetting down burlap used for curing
. Clips for expansion-joint filler
. Muslin or burlap for finishing surface
. Burlap for curing
. Racks for holding burlap or mats to keep same from getting dirty

The Contractor should also have ready the equipment needed to seal the joints with rubberized sealing material* as required by the Specifications. This equipment includes a melting kettle of the double boiler, gas heated, indirect heating type, with a mechanically operated agitator and positive thermostatic temperature control; pouring equipment; air compressor which will maintain 90 pounds per square inch (psi) air pressure, and push type wire brushes with air nozzle attachment.

Checking Subgrade

20. Before any subbase material is placed, the subgrade must be checked for grade, cross section, and drainage. It is especially important that there be no ruts or depressions that will hold water. Any such low

places must be brought to grade with subgrade material, so that water will drain to the sides of the road. Material in any soft or yielding spots should be dug out and replaced with good subgrade material. Subbase material should not be used for filling low spots in the subgrade or making repairs since this material is usually pervious* and would allow water to collect and soften up the subgrade.

Compaction tests must be made on the subgrade just before the subbase is placed to make sure that it has the density required by the Specifications. A subgrade that was once compacted to Specification density*, but which has lost density as a result of being exposed to the weather, must be brought to optimum moisture content* and recompacted. Any loose material added to fill low spots must be compacted by rolling with the specified rollers until all parts of the subgrade, inside the form lines and for a distance of 2 feet outside the form line on each side, are brought to a uniform density meeting the Specification requirements.

Subgrade Drainage

21. The type and location of drains* in the subgrade will be decided by the Assistant District Construction Engineer. The subbase Inspector must see that the subgrade drains are constructed as required by the Specifications and the Department Standards. He must make sure that the drains are cut through the shoulders and have open outlets. They must be ready to work when it rains and not allow water to be trapped beneath the pavement after it is completed. The material placed in drainage trenches must be clear. Building paper must be on hand to cover the filled trenches constructed under a concrete pavement or concrete gutter. The paper is used to keep mortar from the concrete from getting into the drainage material and clogging it.

Importance of Subbase

22. The useful life of a concrete pavement depends a lot on the materials in, and the construction of, the subbase. The purpose of the subbase is to give uniform support to the concrete slab, to allow any water that gets under the slab to drain out to the shoulders, and to distribute loads from the slab to the subgrade. If the subbase has too much clay or silt in it, this material may pump out of the joints or blow out at the edges of the slab when it becomes wet. This will cause the pavement to crack up under traffic. If the subbase is entirely granular, with no binder, the vibrations caused by traffic may cause the subbase material to move away from the joints in the pavement. In extreme cases this movement results in a "turtle-back" pavement having a profile* that is high at the center of each slab and low at the joints.

Preparing The Subbase

23. To get a good pavement the subbase must support the concrete uniformly at all points. To serve its purpose, the subbase must have the same gradation, the same thickness, the same density, and the same

moisture content at all points along the length of, and across the full width of the road. There must not be any sharp changes in support along the length of the project. This means that there must be neither soft places nor hard places due to large stones or rock close to the surface.

To give firm, uniform support the whole subbase must be compacted to a density that is high enough to prevent settlement during the placing of the concrete or later on under traffic. Subbase material is granular*, and it should be compacted at optimum moisture content. After compaction it should be kept moist until the concrete is placed. If it is not, some spots may dry out and lose density.

The subbase must be placed and compacted to a width that extends at least 2 feet beyond the form line on each side. Its surface should be slightly above grade after compaction. It then can be trimmed down to plan grade for setting the forms and placing the concrete. If the subbase material has been compacted properly and the density has not been lost, it will give firm, <u>uniform</u> support. If the subbase surface is too low and material has to be spread on top, this material must be wetted to the right moisture content and rolled with a 10-ton roller the same way as the rest of the subbase.

The rolling of the subbase should be closely watched at all times. If any soft spots show up the poor material should be dug out. If an additional subdrain is needed, it should be put in. In any case, the new material used to bring the hole back to grade should meet the Specifications for subgrade material up to the level of the bottom of the subbase and for subbase material above that level. All the material should be moist enough to be easily compacted. It must be put back in layers and each layer must be compacted. When the hole has been filled, the subbase should be given some extra rolling to make sure that it is firm and that all the soft material has been taken out.

If the subbase material becomes dirty from any cause, such as by mud tracked on by trucks or washed onto the subbase during a rain, the dirty material must be removed and replaced with material which meets the Specification requirements.

Preparation For Setting Forms

24. The first step in setting forms is to transfer the grade* and alignment* from the offset stakes* to the actual form line. Steel pins should be driven not more than 50 feet apart (25 feet on curves) in such position that the side of each pin toward the outside edge of the pavement is on the line to which the inside face of the form must be set. The grade of the top of the forms is then transferred to marks on the pins by using a straightedge, a rule, and a level. A string line is then attached to the pins at the marked grade points and pulled tight. At least 100 feet of stringline should be set at

one time. Variations in alignment or dips or high points in the grade may be located by sighting along the stringline.

If grading is done by hand, the men doing the grading should have some kind of gage. This can be a stick with a notch cut in it, or in the handle of each shovel, a distance from the end equal to the height of the forms. The bed for the form must be accurately cut to the right grade. Undercutting (digging too far) and regrading (refilling) with loose material must not be permitted. The bed should be graded for a width extending slightly beyond the base of the form on each side. When a form grader is used, the same principles apply, but stringline used as a guide must be offset both vertically and horizontally as required. The Inspector should check the grading operation carefully. He must see to it that the form bed* is cut to the right grade, and also make sure that no soft spots have been overlooked. If any such spots are found the material must be dug out and replaced with Specification material rolled to the required density.

Paving on Curves

25. On most curves the pavement slopes upward from the inside edge to the outside edge. The curve is then said to be superelevated. Also, on sharper curves the pavement is made wider than on a straight stretch of road. The Inspector-in-Charge must check the Contract Drawings to find out whether or not the pavement on a curve is to be superelevated, or both superelevated and widened. The cross sections usually show the amount of widening at each station on a superelevated curve. However, the cross sections are to be used as a guide only. The final check must be made by stringline and by eye. Where there is superelevation, the grade is maintained at the low side and the slope is made uniform across the entire width of the pavement.

The pavement will have the right curvature, width, and superelevation on a curve if the forms are set properly. Care must be taken in setting and checking the forms to prevent sharp changes in alignment and grade. Where the pavement is widened, regular side forms are set for the full width of the widened section. It is usually necessary to set false forms for the regular width of pavement and to have the machine run on these forms. After the machine has passed, the false forms are removed, and the remaining space is filled with concrete. This part of the pavement is then screeded and finished by hand.

After the Contractor has set the forms on a curve, the Inspector should check the alignment by measurement from the offset stakes. He should check to see that there is a smooth curve between stakes. The grade of the forms must be checked by eye to see that there are no bumps or dips. The Inspector should never permit paving work on a curve to be started until enough form has been set and checked on both sides and he is satisfied that a good riding surface can be obtained for the whole length of the curved section.

Warped Surfaces

26. On city and borough work, and in open country, at intersections with other improved roads, it is often necessary to warp portions of the surface of the pavement. This is done by making one side lower than the other, in order to meet the grade of the existing pavement.

In some boroughs or cities it may sometimes be necessary to lay out an inverted saucer type intersection instead of carrying the main traffic through in the way shown on the typical sections. This is done in order that the new work will meet the grade of the existing pavement and that drainage can be maintained through the intersection. Stringlines should be set, and the grade to be used worked out and explained to the finishers before paving begins. The Inspector-in-Charge should, in all cases, have the approval of the Assistant District Construction Engineer before any paving of this type is started.

Checking Support For Forms

27. Unless every section of form is set right, the pavement will not have a true surface. The machines that ride on the forms are very heavy and vibrate. If any part of the form is not supported firmly it will sink and the dip will show up in the surface of the finished pavement. Forms must always be set on material that was rolled at the proper moisture content and then trimmed down to grade. If any section of form is too low, it must be taken up. More material must be added, rolled, and trimmed to grade. A stringline should be stretched across the gap in the forms and measurements taken from the stringline to make sure that the grade is right before the form is set back.

Blocking up the form or pushing loose material under it is a sure way to get a poor job. The forms must be solid before the form pins are driven.

The Inspector must make sure that the form setters don't block up the forms or try to use the form pins to hold them up. The forms must be in firm contact with the subbase at all points along their length, and for the full width of the form. Each section of form should be checked for firm contact with the subbase by punching under the form with a stick in several places on both sides.

If the form settles as much as 1/4 inch under the weight and vibration of the equipment, it has not been properly set. To measure vertical movement of a form, drive a form pin next to the form and rub some yellow kiel* on the side of the pin opposite the top of the form. Then, with a carpenter's level, make a pencil mark on the pin exactly level with the top of the form before the Contractor's machines pass over the form. After the machines have passed, use the level to make another mark. The distance between the marks is the distance the form has settled. Too much settlement shows that the Contractor must take action immediately to make the subbase or subgrade more stable.

Checking Alignment

Checking Grade

Subbase Planer

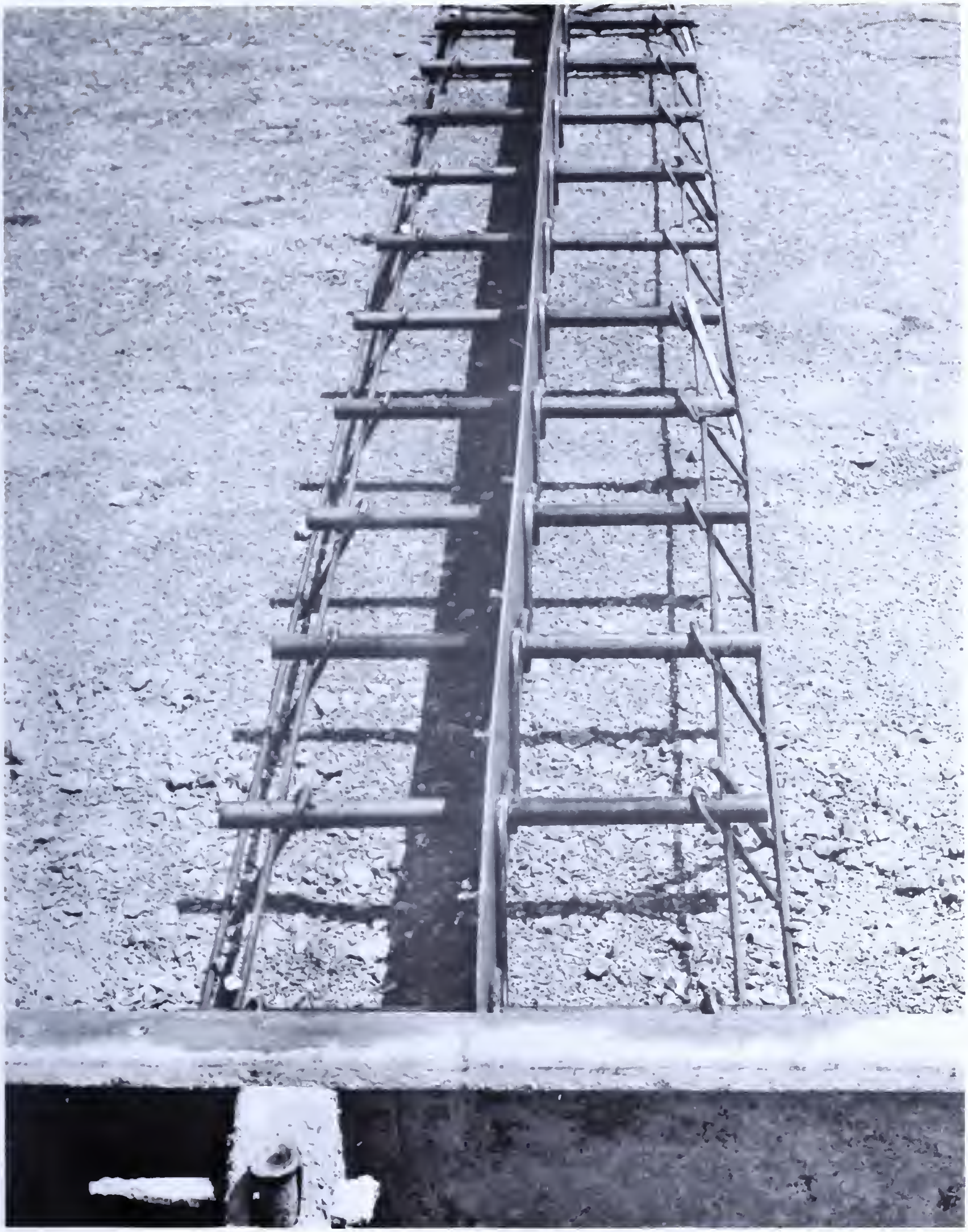
Scratch Board

Wetting Subbase

Expansion Joint

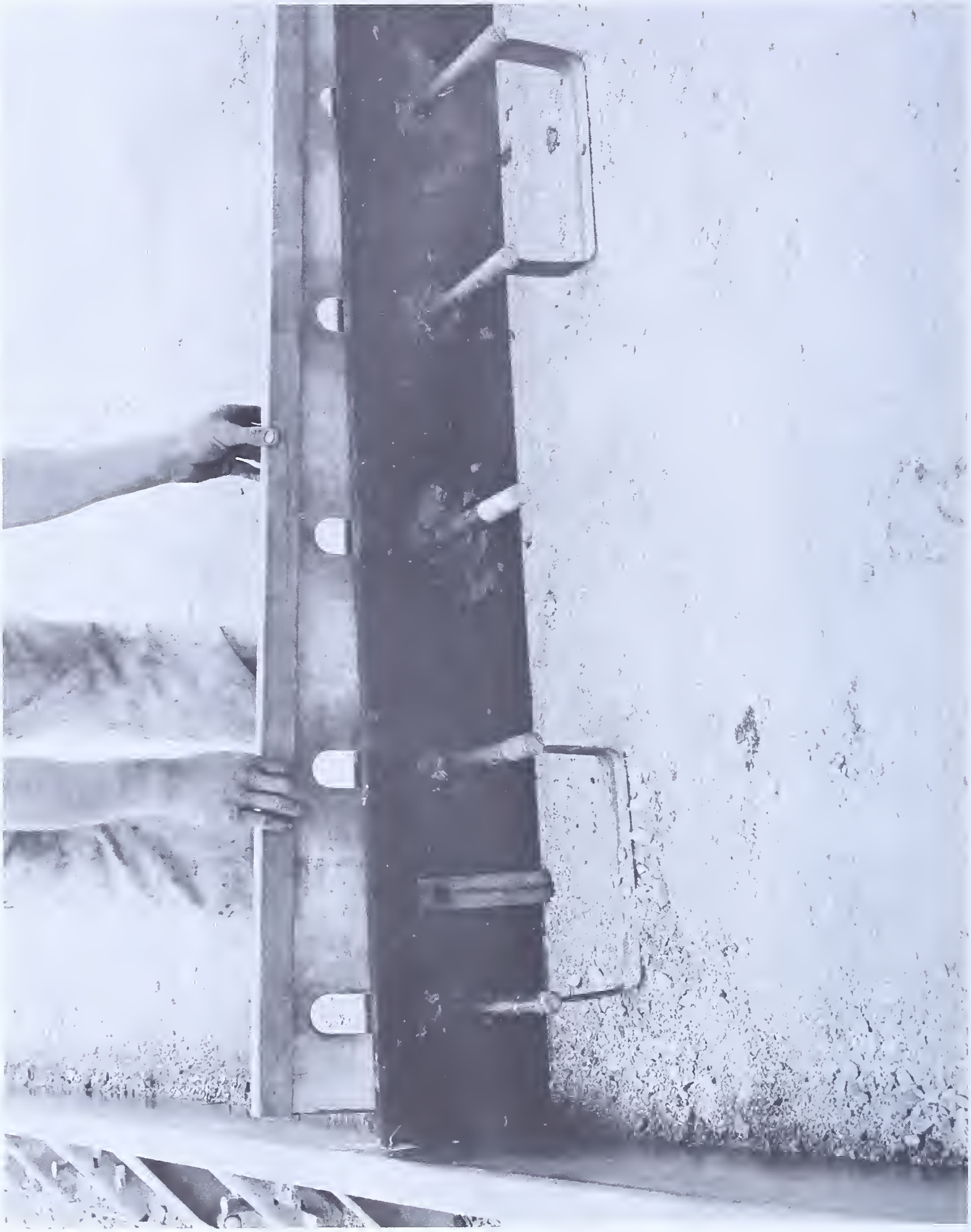
G.B. ✓

Every 10 Bays



Construction Joint

246' to P.C. or P.T.
Town Every 4 Bays



Expansion Joint with Cap

Checking Forms for Alignment and Grade (See VII-16A,B)

28. After the forms are set, the Inspector must check them. They must be plumb and to line and grade on both sides of the lane. Line can be checked by measurement of the offset distance from the fine grade stakes and by sighting along the forms, then the distance between opposite forms must be measured with a steel tape. The elevation of the top of the forms should be checked to make sure that it is the same as that shown on the plans. The forms should also be checked with a straightedge across each joint.

Except on vertical curves, the grade can be checked by sighting along the top of the forms and also by the use of a string line about 50 feet long. The ends of the string line are held above the top of the form by wood blocks about 1 or 2 inches high, and the string line pulled as tight as possible. When it is tight, another block of the same height is slid along the top of the forms and under the stringline, and any high or low places spotted. The line should be moved ahead about 25 feet, and the check made again until all the forms have been checked on both sides of the lane.

The logitudinal keys* must be inspected. Any that have been warped, bent or crimped so that they do not lay evenly against the form, must be rejected. The space between the shield and the form must not be more than 1/16 inch. Dowel shields must be placed or cut so that they will not be closer than 6 inches to any transverse joint.

THE CHECKING OF THE FORMS IS A MOST IMPORTANT PART OF THE CONSTRUCTION INSPECTION. THE PAVEMENT CANNOT BE BUILT TO THE PROPER LINE AND GRADE UNLESS THE FORMS ARE SET RIGHT.

Checking Cross Section of Surface of Subbase (See VII-16C)

29. After the forms have been set and checked, the subbase between the forms must be fine-graded. This is usually done with a mechanical subgrader or a subbase planer. After fine grading, some loose material may be left in low spots in the grade. This material must be wetted down and compacted.

After the fine grading is completed the subbase surface must be checked with the subgrade tester. If the points of the spikes leave any marks in the subbase, the subbase must be trimmed down and checked again with the subgrade tester.

The wheels and pins of the tester must be kept clean, and it must be handled carefully. In general, the final check on the subbase should not be made on more than about four joints or bays ahead of the mixer. The reason for this is that under some conditions the subgrade or subbase material may swell* and the surface of the subbase may be raised after the joint assemblies have been set.

The Mixer Inspector should check the subbase and the tester the first thing in the morning before mixing starts and again at noon. He may have to check it at other times, but paving operations should not be held up too much. It will save time if the Contractor checks the subbase first, but the Inspector must make his own check. He is the one who will be held responsible if any of the concrete test cores taken from the pavement by the Laboratory are short because the subbase surface was left too high, even though the Contractor will be penalized and get less money for thin pavement or be required to remove it.

The final step in checking the subbase is to make sure that any extra material at the edge of the lane is leveled out or removed. The lower inside edge of the forms must show. If this is done, the pavement will always have the full thickness at the edge.

Wetting Down Subbase (See VII-16E)

30. Before any concrete is placed the subbase must be moist, but not saturated. It must not take any water from the concrete. Loss of water would affect the uniformity of the water/cement ratio and the concrete might shrink and start to crack. As much as possible of the fine grading should be done the day before the concrete is to be placed. The subbase then can be given a good wetting down and will have time overnight to come to a uniform moisture content. If it dries out on top it must be sprinkled just before the concrete is placed.

To prevent trouble caused by swelling of the material in the subgrade or subbase, the subbase should be checked at the mixer every morning before paving operations are started. If any swelling is found, corrections can be made and the dowel shields and dowels at the joints can be reset without holding up the paving work. Failure to check the subbase just before the paving is started may result in short cores*.

Transverse Expansion Joints (See VII-16F, G)

31. The way expansion joints are to be installed is shown on the Drawings and is described in the Specifications. More details are shown on Sheet B-1 of the Standard Drawings. The purpose of the expansion joints is to allow the pavement to move slightly when the concrete slabs become longer because of high temperatures, increased moisture content, or the slow "growth" that occurs in concrete over a long period of time. If the pavement could not move, the expansion would cause cracking and spalling of the concrete slabs, or possibly buckling (raising up) of the pavement at a joint or crack.

An expansion joint is made by putting a strip of pre-molded joint filler between the ends of 2 concrete slabs. This pre-molded joint filler is made of a material that is easily squeezed into a smaller space when the pavement expands. The filler is fixed in position by a metal shield held firmly in place on the subbase. The load transfer dowels

pass through holes in the joint filler, but there must be no spaces where concrete can pass through, or around it.

To work right, the expansion-joint material must be exactly at right angles to the edge of the pavement (or along a true radius if the pavement is on a curve). The load transfer dowels must be exactly parallel to the surface of the pavement. One half of the length of each dowel must be free to move in the concrete. There must be enough space (formed by a cap on the free end of the dowel) so that the dowel can move the full distance allowed by the expansion-joint material without hitting the concrete. The joint assembly must be held firmly in place, and be at right angles to the forms (along the radius when on a curve).

Checking Alignment of Transverse Joints

32. An easy way to find if a joint has been installed at a right angle (or on a true radius if on a curve) is to fasten the free end of a tape at the point one end of the joint meets the form (the outside form when on a curve). Pull the tape at an angle across the lane to the other form. Make a kiel mark at a point where some even foot reading on the tape meets the form (this can be about 15 feet for a 12 foot lane and about 30 feet for a two-lane width of 24 feet). Hold the tape at the foot mark used and swing the held end of the tape to the other side of the joint. Make another kiel mark where the foot mark meets the form. Measure the distance from each kiel mark to the end of the joint. If the joint has been properly installed, the distance from the end to either kiel mark will be the same.

Placing Joint Assembly

33. The joint assembly must be set so that the pre-molded expansion-joint material will, at all points, be 3/4 inch below a stringline stretched across the tops of opposite forms. A transverse joint must be straight for the entire length. It is very important that the strips of expansion-joint material butt tightly at each logitudinal joint. There must be no space in the joint where mortar can flow around or through the expansion-joint material. If expansion-joint material has been punched for dowels and the dowels are not used, the holes must be plugged with expansion-joint material, cut to the size and shape to fit the holes. Expansion-joint guides (Sheet B-1 of the Standard Drawings) are to be used at ends of the expansion-joint material to make sure of free ends next to forms.

When dowels are required in expansion joints, they must be set very carefully and held in place so that, after the concrete is placed and has hardened, one end of each dowel will be free to move. The Inspector must make sure that both ends of the dowels are the same distance below the top of the forms by measuring from a stretched stringline. Each

The portion of the hook dowel first installed, that is, the part attached to the metal keyway, must be placed with the long vertical leg pointing downward. The nuts must be tightened so that the dowel is held tightly. The dowels must be spaced as shown on Sheet B-1 of the Standard Drawings. A different spacing is used near transverse joints and the measurements should be checked against those shown on the Standard Drawings.

When two-lane pavement is placed full width at one time, the dowel shield, or metal keyway, is not used. Instead of hook-dowels, #5 reinforcing bars, 4 feet long, are placed in the first layer of concrete so that they will be at 1/2 the depth of the completed pavement. These bars can be placed in the correct position with a device which will push them into the concrete, or installed by some other approved method. They are spaced as shown on Sheet B-1 of the Standard Drawings. After the concrete has hardened a groove for the longitudinal joint is sawed. This is described later.

<u>Reinforcement for Approach Slabs to Structures</u>

36. Additional reinforcement is required for the pavement, or approach slabs, next to bridges and other rigid structures. Details are shown on Sheet B-1 of the Standard Drawings. The reinforcing bars must be clean and tightly fastened together by wires or ties so they will not move when the concrete is placed. The reinforcing bar assembly, or mat, should be held 2 inches above the subbase by concrete blocks, spaced about 2 feet on centers, to prevent the mat from being forced down by the weight of the fresh concrete.

<u>Items to be Checked Before Paving</u>

37. The Inspector ahead of the mixer is responsible for checking to see that everything is ready for the placing of the concrete. It is his duty to see to it that:

(a) The subbase has been graded below the top of the forms to the right elevation and to the shape of the bottom of the pavement.
(b) At least 750 feet of prepared subbase and forms are set to line and grade ahead of the mixer at all times for one-lane construction, and not less than 500 feet for two-lane construction.
(c) The forms meet the requirements of the Specifications and are clean, straight, set on a solid foundation, and able to take the weight of the paving equipment without displacement or settlement.
(d) The cable from the subbase planer is not anchored to the pins holding the forms.

(e) The subgrade tester is checked each day before work begins, again at noon, and at other times, whenever necessary.

(f) Entire subbase is checked with the tester, at least 250 feet ahead of the mixer.

(g) The forms are oiled and the bottom inner edge of the form is showing.

(h) The longitudinal dowel shield is tightly fastened to the forms, held so that it will not get out of line when the concrete along the forms is spaded and vibrated, and that the long leg of each hook dowel is turned down. When the next lane is paved, the short leg of the hook dowel may point in any direction, as long as it is tight.

(i) The dowels are correctly spaced and supported. Each dowel cap has been put in place and checked for free space at the end of the dowel. Graphite paste on the dowels is in good condition.

(j) The transverse expansion joints and construction joints, are located at the right places and the joint assemblies staked so they cannot move.

(k) There is no extra subbase material at joints, and there are no spaces below or at the ends of the expansion-joint material.

(l) The load-transfer units are placed and held so the dowels will stay in position at approximately one-half the depth of the slab.

(m) The additional reinforcement for approach slabs is in position, properly spaced and held above the subbase, also that the expansion-joint material is fastened to the vertical surface of the seat at end of the bridge slab.

(n) The subbase is kept moist.

Batch Mixed Concrete

38. To get a good pavement that will last, the concrete must be uniform. This means that every batch, and every part of every batch, must have the same proportions of water, cement, entrained air, and aggregate. The proportion of fine aggregate to coarse aggregate must be the same.

All concrete shrinks after it is placed. This shrinkage is caused mainly by loss of water. When concrete is first placed some water rises or "bleeds"* to the top. The more water that bleeds off the more the concrete settles or shrinks down. The amount of bleeding depends mostly on the amount of water in the mix, how fine the cement was ground, and how much entrained air there is in the concrete. If there is more air or less water in the concrete at one place in the pavement than at another, the concrete at the first place will bleed less and shrink less before it has set up. This difference will leave a high spot in the pavement which must be cut down during finishing.

The Specifications give the requirements for a mixer that can produce uniform concrete. The Inspector, the Inspector-in-Charge and the Assistant Construction Engineer all must check the concrete mixer before it is used to make sure that it is in good condition and meets the Specifications. The Inspector should read over again the part of the Specifications which cover the mixing of the concrete. Also, he should try to get a copy of the manufacturer's catalog and operating instructions from the Contractor. Things that should be checked to make sure that the mixer meets the Specifications are the mixer blades, the timer, the water measuring tank and valves, the mixer bucket and skip.

A mixer that has been used before may have the blades worn down so that it cannot do a good job of mixing. If any part of a blade is worn down more than 3/4 inch below the size shown by the manufacturer's specifications, that blade must be replaced. As described under initial inspection of equipment, it is necessary to check the water gage by measuring the amount of water actually added to the batch for several gage settings. The valves must close tightly. If a valve leaks, there will not be the same amount of water in each batch and the concrete will not be uniform.

The timer, skip and bucket should have been examined during the initial inspection of equipment. However, they should be checked again when the first concrete is mixed. The timer must be set so that it measures the actual mixing time. This time begins when all the materials are in the mixer and ends when the first concrete is discharged. The required mixing time for different conditions is given in the Specifications. The skip of the mixer must clean itself when the batch is dumped into the paver. It must not allow any of the batch to spill out when trucks dump the batch into it or when it dumps the batch into the mixer drum. The bottom of the bucket must close tightly to prevent mortar from dripping out.

When the mixer is operating on pavement, any mortar that drips from the mixer drum or bucket must be caught in a splash pan or tray. If, by special permission of the District Engineer, the mixer is operating on the subbase between the forms, any mortar that drops onto the subbase must be picked up with a shovel and thrown outside the forms.

An approved automatic dispenser is required when air-entraining agent is added at the mixer. It is important that the right amount of agent be added to every batch of concrete. The equipment should be checked often, and if it is not reliable, it must be fixed, or replaced, before any more concrete is mixed. There must always be a good supply of agent in the tank.

Before operations are started each day the Inspector must see to it that the mixer skip, mixing drum and discharge bucket are clean and that the drum and bucket have been flushed out. He must see that the water tank is full and that the valves are not leaking.

The Inspector must check the slump* of the concrete if it is too stiff when the amount of water called for by the Batcher-Mixer Slip, Form 4220, is being used, he should find out why. The first step is to check with the Plant Inspector, have a test made of the moisture content* of the aggregates and have a new Batcher-Mixer Slip, Form 4220 issued. The Inspector should also check to make sure that the Plant Inspector has tested the temperature of the cement. The temperature of the concrete may be too high because of the use of hot cement, warm mixing water from a long temporary pipe line, or aggregate from stock piles that were not sprinkled with water.

<u>Ready-Mixed or Transit-Mixed Concrete</u>

39. Each mixer truck must have been approved and must be checked by the Mixer Inspector on the job at least once a week during operation to make sure that it meets all specification requirements. Some of these are:

- (a) The revolution counter must be in working order (must be set to zero by the Plant Inspector).
- (b) The gage on the mixing water tank must be properly calibrated and in working order.
- (c) The wash water tank must be filled and all valves must be checked for leaking.
- (d) The water measuring tank must be able to discharge all the measured water into the mixing drum in one-fourth the mixing time.
- (e) The drum must make between 8 and 12 revolutions per minute. (The actual number can be found by making kiel mark on drum and counting revolutions made during one revolution of the second hand of a watch).
- (f) There should be no leaks around the charging door or discharge doors.
- (g) The Inspector must get a list of the mixer trucks that have been approved for use on the job.

The Specifications do not permit dumping of concrete directly onto the subbase from a truck mixer. The mixer must discharge into an approved strike-off machine that will distribute the concrete uniformly over the full width of the lane. When trucks are discharging, the door should be opened fully and the rate of discharge should be controlled by the rotation of the drum. If the door is kept partly closed, the chance of segregation of the mortar and aggregates will be increased greatly. The concrete discharged last will have too high a percentage of coarse aggregate.

When concrete is supplied by a truck mixer, the Inspector must check every truck when it starts to dump and see to it that the slump of the concrete is not higher than allowable. The Inspector is dealing with a number of mixer operators, and some of them may not be familiar with job requirements. Delay may be avoided if he has the concrete foreman warn each operator, individually, that concrete of too high a slump will not be accepted.

The mixing action in a truck mixer is not so vigorous as that in a paver or central plant mixer. A much longer mixing time is needed in a truck mixer to get the same results. The Specifications require that all concrete from truck mixers be mixed for at least 50 revolutions of the drum (70 revolutions when the rated capacity of the mixer is exceeded as permitted). Since the drum turns about 10 revolutions per minute at mixing speed, the mixing time must be at least 5 (or 7) minutes. The exact number of revolutions, as shown by the counter, should be checked before the truck starts to dump.

If more mixing water is required at the job, it must be mixed in the batch by having the drum make at least 20 more revolutions. Since continued mixing tends to dry up the concrete, it may take a flash set if mixed too long. The Specifications limit the mixing time to 100 revolutions at mixing speed. If the concrete must be held in the drum after 100 revolutions have been made the drum speed must be reduced to 2 to 4 revolutions per minute. The slower speed should be checked as before.

When the trucks are held a long time on the job, the Inspector should make sure that the driver does not add more water to make up for the loss of slump that occurs even at the lower drum speed. At lower temperatures the concrete cannot be used if more than 1-1/2 hours have passed since the water was first mixed into the batch. When the air temperature is more than 85 degrees F., this time is reduced to 1 hour. When calcium chloride is used in the mix for cold weather curing, the load must be dumped within 30 minutes. If calcium chloride is used during normal weather, the total time after start of mixing, must not be more than 20 minutes.

Central Plant-Mixed Concrete

40. The Specifications require that concrete mixed at a central plant be delivered to the job in truck mixers or revolving drum agitators. Delivery of the concrete in trucks with non-agitating or "dump-crete" bodies is not permitted unless the bodies have been approved. In general, the addition of water to central plant-mixed concrete should never be permitted. The only possible exception would be cases where the Specifications for truck mixed-concrete would apply.

Batcher-Mixer Slip Form 4220

41. The use of a Batcher-Mixer Slip, Form 4220, is an important part of concrete paving control. Every Department Engineer who visits the job will ask for the current Form 4220. The amount of mixing water specified for a batch of concrete will be checked against that actually set on the mixer gage. As soon as a Batcher-Mixer Slip is received the mixer gage should be reset, and the Mixer Inspector should make three slump* tests, and average the results. This average should be within 1/2 inch of the design slump. He should also make a test to determine the air content of the concrete. If the water required at the mixer to produce the design slump does not differ from that noted on the Form 4220 by more than 0.2 gallon per bag of cement, no action is necessary.

If too much or too little water is required, the Mixer Inspector should have the mixer gage adjusted to give the correct slump. Also, he should send a note immediately to the Plant Inspector requesting that another moisture test be made on the aggregates and a new Form 4220 issued. If, at any time, the slump changes and the water content must again be changed to give the correct slump, the same procedure should be followed.

Slump Test

42. The standard method of making the slump test is described in Chapter XI of this Manual. The directions given should be followed exactly so the result will be accurate and the consistency of the concrete kept uniform. It is important that the method of sampling the concrete for the test be such as to obtain a truly representative sample, one which has the same proportions of mortar and coarse aggregate as the average batch of concrete in the pavement.

Slump tests should be made after the first few batches of concrete have been mixed, and whenever the consistency of the concrete changes. Slump tests must be made before any change is permitted in the amount of water added to the batch. Slump tests must also be made at the same time test beams* are molded. At least three sets of slump tests, each set consisting of three tests, should be made each day.

Unit Weight of Concrete (Weight Per Cubic Foot)

43. The weight per cubic foot of concrete is usually not a required test. When made, this test requires that use of an accurate platform scale which must be kept near the mixer. Along with the test for air-entrainment, it is a valuable tool for checking concrete quality at the point of use, and at the time when the placing of poor quality concrete can be prevented. A decrease in the weight of the solid volume of concrete shows that quality and strength have been reduced. This is because an increase in the gallons of water used per cubic yard of

concrete, or a decrease in the amount of cement actually added to the batch, will reduce the weight per cubic foot of the solid volume. The sample of concrete must be taken in the same manner as for the slump test, and the weight per cubic foot of the concrete determined. The weight per cubic foot of solid volume of concrete is found by dividing the weight per cubic foot by 100 minus the percentage of entrained air. Details of the method of making the test are given in Chapter XI.

Any decrease in weight per cubic foot of solid volume of concrete means that the weight of cement, and the amount of water, actually being added to each batch of aggregate, should be checked immediately.

<u>Test for Air-Entrainment</u>

44. Tests for the percentage of entrained air* in the concrete should be made frequently and carefully, because the amount of air has a great effect on the strength, durability, and the yield of pavement concrete. If there is not enough entrained air the concrete will scale on the surface and pieces will spall off under repeated freezing and thawing. Some water always soaks into concrete. When this water freezes and forms ice, it takes up more space. This expansion will break up the concrete, unless there is some room for expansion. The very small spaces left by the bubbles of entrained air provide this extra room. Tests and experience have shown that at least 4 percent entrained air is needed to protect the concrete from the effects of repeated freezing and thawing.

Although entrained air protects the pavement from damage due to repeated freezing and thawing it reduces the strength of the concrete. If the amount of entrained air is above 7 percent the pavement may be weakened seriously. To get a good pavement, <u>every</u> batch of concrete must have at least the minimum amount of air allowed by the Specifications. Best results are obtained if the air content is kept <u>uniformly</u> at about 5 percent.

Changes in the amount of entrained air from batch to batch can affect the riding qualities of the pavement. Batches with low air content will bleed out more water than those with more air, and the greater shrinkage will cause a low place in the pavement. Unless this dip is taken out during the finishing operation, the pavement will not have a perfectly smooth riding surface. Any large changes in the air content should be reported to the Inspector-in-Charge.

Even though an air-entraining agent is ground into the cement at the mill, the amount of entrained air cannot always be controlled at the job unless additional air-entraining agent is added at the mixer. The air-entraining agent blended in at the mill does not always produce the same results under different job conditions. Many things affect

the amount of entrained air besides the amount of air-entraining agent. When necessary to bring the amount of entrained air up to the percentage required by the design and Specifications the additional agent must be added at the mixer by the use of an approved dispenser.

Making Test Beams

45. The Mixer Inspector supervises the making of test beams of the pavement concrete. At least one set of beams should be made for each one-half mile of pavement. The assistant District Construction Engineer will fill out a copy of form 458C showing the locations from which samples are to be taken for beams. If there is any trouble with the concrete or any doubt about its quality, more beams should be made.

Details of the methods of sampling the concrete and making the beams are given in Chapter XI. Concrete for beams on a paving job usually is sampled from a batch which has been dumped on the subbase. Extra care must be taken to get a sample that has the same proportions of the large coarse aggregate in it as has the concrete in the pavement. The amount of coarse aggregate in the beam has an effect on the test results.

Preparation for Mixing Concrete

46. Before paving is begun, all items on the check list covering subbase, forms, and joints must be attended to, and the grade of the subbase on which the concrete will be first placed checked. When the concrete is to be mixed in a paver the Mixer Inspector must check the preparations for mixing. The mixer skip must be clean and the mixer drum and bucket must have been flushed out. Other things that must be checked are:

> The wire mesh* must be at hand and not bent or pulled out of shape. It must be the right type as shown on the Plans.
>
> Enough workmen must be on hand to do all required operations.
>
> All placing and finishing equipment must have been checked.
>
> The Batcher-Mixer Slip, Form 4220, must be obtained from the first truck and water gage on the mixer set to the number of gallons shown on the slip.
>
> The water tank on the mixer must be full.

While the first batch of concrete is being mixed, the Mixer Inspector must check the operation of the mixer timer and make sure that the batch is held in the drum for the specified mixing time.

As soon as the first few batches of concrete have been placed, the slump and air content should be checked.

The trucks should be inspected while being dumped during the first round, to make sure that each partition between batch compartments fits tightly and releases properly. If cement compartments are used, they must empty completely. Unsatisfactory trucks must be barred from the job.

Placing Concrete

47. The concrete must be dumped and spread on the subbase as rapidly as possible and without delay between batches. It must be spread immediately to about the required depth by machine or, with the approval of the District Engineer, by workmen using hand tools. When the concrete is mixed by a paver it can be distributed over the subbase by changing the direction of the boom and the distance at which the bucket is emptied. The Mixer Inspector should see that the mixer operator spreads the concrete out uniformly to a depth a little greater than the required depth. The concrete should not be dumped in a high pile and then spread. The concrete would then segregate* and it would be hard to spread the material in the middle of the pile. As a result, a bump probably would be left in the surface of the pavement that could not be taken out easily during finishing.

Blade or screw type spreaders can handle very stiff concrete. However, the concrete should be spread as much as possible by the bucket, in order to make spreading easier. Before the spreader is used, the elevation gage should be checked to make sure that it reads zero when the strike-off plate is exactly even with the top of the forms. It will then be easier for the Inspector to be sure that the concrete is struck off at the right depth for the wire mesh. On the final pass of the spreader a little extra concrete must be left for the finishing operations.

The Mixer Inspector must watch the concrete as it is dumped from the bucket and make sure that it is not too dry or too wet and that it does not segregate*. There should be about the same proportion of large aggregate in all parts of the batch after it is dumped on the subbase. If there is a "nest" of large stones in one place, the concrete in the batch is segregated and the batch must be removed. There is something wrong either with the mix or with the mixing operation and steps should be taken to correct the situation.

Spreading Concrete By Hand (See VII-32A)

48. If the concrete is to be spread by hand, the Inspector must tell the concrete foreman not to let the workmen use their shovels too close to the subbase so as to get subbase material mixed in with the concrete. When they shovel the concrete against a form, joint, or any other surface they must not throw it, but must place it by turning the shovel so

that the back, or bottom surface, of the shovel is against the form or joint when the concrete slides off. This gets the mortar against the form or joint, instead of the large stones, and reduces segregation. This makes the concrete easier to compact. The workmen must spade the concrete along the forms and other surfaces with which it comes in contact. The spade should be slid down close to the form and then tipped away from the form. This method lets out the air bubbles and pushes the large stones away from the form. When the forms are stripped the sides of the pavement should be perfectly smooth. If there is "honeycomb"*, the concrete has not been spaded right.

When the spud vibrator* is used, a workman must not leave the spud in one place more than 5 seconds. If he does, the concrete in that place will become so liquid that the large stones will sink to the bottom. There will be too much mortar on top, which will make a weak place in the pavement. The mortar shrinks more than the rest of the concrete, and this uneven shrinkage may cause a crack. Vibrators are to be used only to consolidate the concrete; they must never be used to move or spread concrete.

Particular attention should be paid to the spading and vibration of concrete at the point where a transverse joint meets a form line or existing pavement. Honeycomb is very apt to occur in these right-angle pockets, and an extra effort must be made to prevent it.

To get a good job, concrete must be shoveled against all forms and joints well ahead of the mechanical spreader. It is particularly important that uniform concrete, with no segregation, be placed on both sides of each joint assembly. This operation must be inspected carefully to make sure the dowels are not moved, and the dowel caps at the expansion joints are not knocked off or damaged.

<u>Placing Tie-bars for Sawed Longitudinal Joint</u>

49. When both lanes of a two-lane pavement are placed at one time, and the longitudinal joint is to be sawed, the tie-bars* must be placed in position in the plastic concrete after it has been struck off and before the mesh is placed. The tie-bars may be placed with a device that holds the bars while they are being pushed into the concrete, or by other approved methods. When in place the bars must be at the center of the total depth of the pavement and must be parallel to the surface. Sheet B-1 of the Standard Drawings should be checked for the exact spacing of the bars from transverse joints and from bar to bar in the center of the slab.

<u>Installing Wire Mesh Reinforcement</u> (See VII-32C)

50. The Inspector-in-Charge is responsible for making sure that each shipment of the wire mesh reinforcement has been sampled, that samples have been sent to the Laboratory, and that all Specification requirements have been met. The purpose of the wire mesh reinforcement is to

reduce the number of cracks in the concrete pavement. If a crack does form, the wire mesh keeps the crack from opening. If the concrete on opposite sides of the crack is held tightly together, the pieces of coarse aggregate that bridge across the crack will prevent the concrete on either side of the crack from moving up or down and making a bump in the road.

To get a good job the mesh must be placed at the right depth in the pavement and the sheets must be lapped as shown on Sheet B-2 of the Standard Drawings.

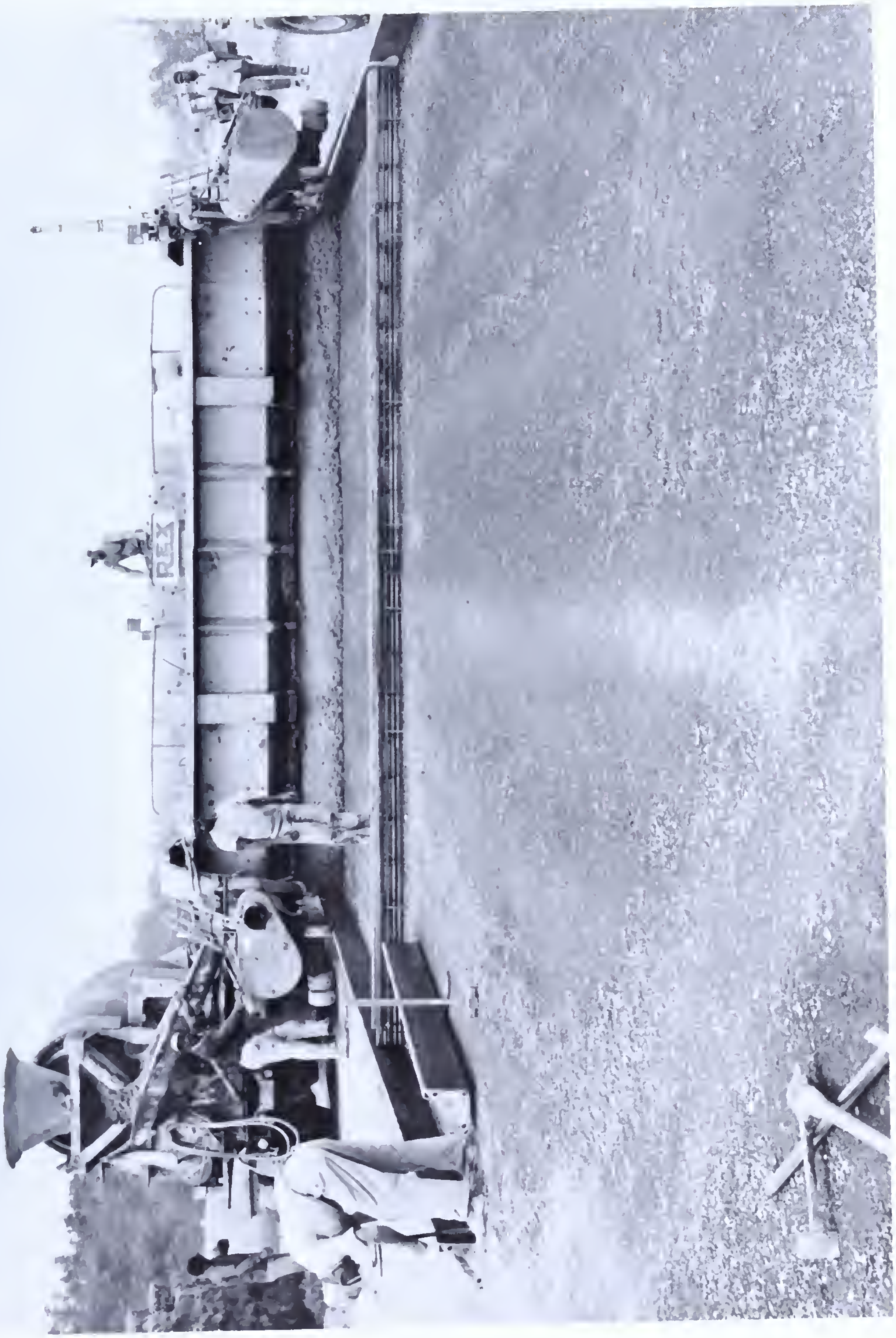
The first pass of the spreader must leave the surface of the concrete on which the mesh is placed at an elevation which will result in the mesh being 2 inches below the surface of the completed pavement. The exact setting of the strike-off usually has to be found by experiment. The surface of the concrete on which the mesh is placed must be as smooth as possible. If hills and valleys can be seen in the surface of the first lift of concrete, where it meets the side form, the strike-off is probably not carrying enough concrete ahead of it. The Standard Drawings require that the mesh sheets be overlapped at least 1 foot both along the length of the lane and across it. It is especially important that the last transverse wire in one sheet overlaps the first transverse wire in the next sheet. At a lap, the sheet nearest to the start should be laid so the end overlaps the sheet farthest from the start.

If the mesh is pushed accidentally too far into the concrete, it must be raised back up to the right position. The lifting can be done with a tool that is made of 1/4-inch rod and has a hook bent on one end and a "T", or loop handle, on the other end.

When the top layer of concrete is being placed, the mixer bucket must spread the concrete in a thin layer on top of the mesh. If too much concrete is dumped in one place, its weight will push the mesh down. In case the concrete spreader tends to push the mesh ahead while spreading the second layer of concrete, the first sheet of mesh must be held in place by metal stakes and all the sheets wired to one another so that they will stay in place.

<u>Placing Second Layer of Concrete</u> (See VII-32E)

51. It is important that the second layer of concrete be placed on the mesh before the first layer has started to set up. If the placing of the top layer is held up too long there may be a lack of bond with the first layer and there may be a weak place between the two layers. In such a case, the top 2 inches of concrete may, in time, come loose from the bottom layer. To prevent this, only a small amount of concrete (one or two sections between joints) can be placed in the first layer before the mixer is brought back to place the second layer. When two mixers are used, the distance between them must be such that the top layer is always placed on concrete that has not started to set up.

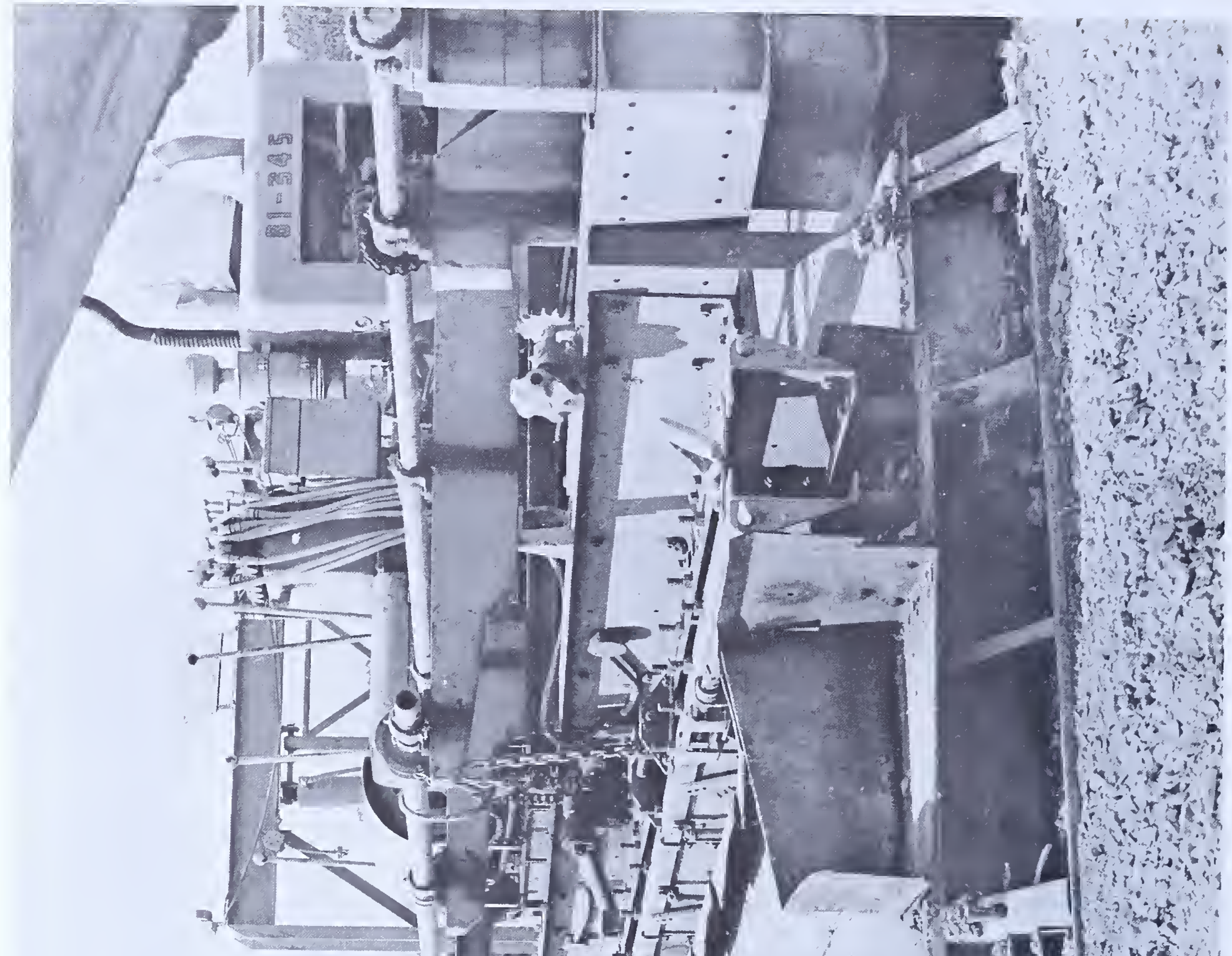


Placing Concrete

Hand Spreading at Joint

Reinforcement 14' long 1' overlap

Wire Mesh



Machine Finishing Concrete

Placing 2nd layer of Concrete

Straight Edging

Edging

Belting

Consolidation and Machine Finishing (See VII - 32D)

52. Requirements for the machine equipment used in finishing the surface of the pavement are given in detail in the Specifications. After the top layer of concrete has been struck off by the spreader, it must be compacted and finished. The greater part of the compaction is done by the first transverse screed of the finishing machine. It usually is set about 1/16 inch to 1/8 inch higher than the second transverse screed to allow for further consolidation and shrinkage of the concrete. The first screed usually is tilted so the leading edge is higher than the trailing edge (about 1/8 inch higher for air-entrained concrete). The first screed should carry a roll of concrete about 4 inches high ahead of it at all times. This roll of concrete should have the same height all along the length of the screed. If the whole roll is too high, or too low, the strike-off must be set to leave the right amount of concrete for a 4-inch roll. If, for any reason the height of the roll starts to drop along a short part of the length of the screed, concrete must be brought back from the pit with shovels and spread along the low place.

The second transverse screed of the finishing machine usually has little or no tilt. Its main purpose is to smooth the surface of the concrete and leave it at the right grade and in condition for final finishing. This second screed should carry a roll of mortar not more than 2 inches high ahead of it on the first pass. If this roll is too high, or too low, the setting of the first transverse screed must be changed up or down to leave the amount of concrete that will give a roll of the right height.

The screeds should move from side to side about six times while the machine moves forward 1 foot. If the concrete sticks to the screed and the screed leaves a torn surface, the number of side to side movements of the screed should be increased. In case too much mortar is being worked up, the mix should be checked to make sure it is the same. If the mix is the same the number of side to side movements should be decreased, and the forward speed increased. If too much mortar is brought to the surface and it is not removed by later operations, scaling of the surface may result.

The Mixer Inspector must not try to make any adjustments of the equipment and he should not tell the Contractor what adjustments to make. However, the Inspector should know that the machine can be adjusted so as to do a good job, and he must insist that the Contractor do whatever is required to produce good results. If the Contractor does not attempt to correct the situation, the Inspector should notify the Inspector-in-Charge who should, in turn, notify the Assistant District Construction Engineer. If the work is not acceptable, the work should be stopped until the required corrections are made and the location of the poor work should be recorded in the Job Diary.

When the finishing machine is working right it should shape and finish the surface of the pavement in two passes. On the second pass, the machine should be run as far as possible without stopping. This distance should be at least 50 feet. Long runs leave fewer bumps in the pavement. On the second pass, the second screed should carry a roll of concrete not more than 1 inch high ahead of it. The Inspector must see that the machine wheels and the tops of the side forms are cleaned off for the second pass so that a perfect surface may be obtained. Extra concrete on the wheels and tops of the forms will cause the finishing machine to ride too high and would result in an uneven surface. After the final pass of the finishing machine, the depth of the mesh below the surface should be measured at several points and recorded. If this depth is greater or less than the specified 2 inches, the strike-off should be adjusted.

The screeds of the finishing machine are held up by wearing plates which slide on the forms. These plates should be checked daily. When they wear down, the screeds will drop below the right height.

The Specifications require that the Contractor have two complete sets of hand finishing equipment available at all times. This equipment can be used only by permission of the District Engineer and it is usually used only in case of a breakdown of the finishing machine, or for widened sections. The Contractor must have men on the job who know how to use this equipment to produce a finish meeting Specification requirements.

Machine Floating The Surface

53. The surface of the pavement usually is given its final machine finish with a longitudinal finisher. How well this machine is adjusted and used can make the difference between a rough pavement and a good job. If the longitudinal finisher does the job that it is supposed to do, very little hand finishing is required. After the finisher is set on the forms it should be inspected and its adjustments checked.

It must be clearly understood that the Mixer Inspector is not to make adjustments of the machines, or to tell the Contractor what adjustments to make. The Inspector's job is to check the adjustments. If he believes that the machine has not been adjusted properly he should warn the concrete foreman and report the matter to the Inspector-in-Charge immediately.

If the transverse finishing has been done right, the longitudinal finisher only has to smooth out the surface of the concrete. Except for the last two feet of the length of the float* it should carry only a little mortar as it moves across the lane.

If the float digs into the surface, the machine should be stopped and the extra concrete removed with shovels. If there is no material in front of the float, some fresh concrete from the pit must be carried back with shovels and spread in front of the float to prevent a low spot. If there is a lot of mortar in front of the float, it must be carried to the edge of the lane by the float and dumped over the forms. This mortar must always be wasted. It should never be thrown back on the slab.

The time at which the longitudinal finishing is done is very important. The concrete is continually settling, because of loss of water and air, until it has started to set. If it is finished too soon, more settlement will take place. Since this settlement is never uniform, an uneven riding surface will result.

The right time for longitudinal finishing depends on the set* of the concrete. The speed of setting changes with temperature, humidity, wind and other conditions. It is impossible to know ahead of time how closely the longitudinal finisher should follow the transverse screed. An experienced Inspector learns to judge the set of the concrete and the right time for longitudinal finishing by testing the surface with his thumb.

When a combination finisher is used it does the same job as the second pass of the transverse screed and also takes the place of the longitudinal finisher. Runs should be as long as possible, and the operation should be held back until the concrete is ready for final finishing. <u>IN ANY CASE, THE LONGITUDINAL FINISHING SHOULD BE HELD AS FAR BEHIND THE TRANSVERSE SCREED AS IT CAN BE AND STILL GET A GOOD FINISH ON THE CONCRETE.</u> If the final floating is done at the right time, if the machine is properly adjusted, and if its wheels and tops of the forms are kept clean, very little hand finishing is required.

Some brands of cement are ground finer than others and will take an initial set* very quickly when calcium chloride is used in the mix. When calcium chloride is used, the concrete should be watched very carefully in order that finishing can be completed before the surface of the concrete gets too hard. Sprinkling water on the surface to make finishing easier is not permitted under any circumstances. This extra water weakens the cement mortar on the surface and will cause scaling*. If the concrete seems to be setting too fast the Inspector should shut down the mixing operation until the finishing and joint work can catch up.

<u>Straight-edging</u> (See VII - 32F)

54. If the longitudinal finishing has been done at the right time, the straight-edging operation should follow immediately. Straightedges should be used to remove mortar and other extra material from high points, and not to work mortar into low places. When the straightedge is pushed toward the center of the slab, the handle should be

held down so that the front edge of the straightedge will be raised and will not dig into the concrete. When the straightedge is pulled back, the handle should be lifted up. On two-lane construction, the straightedge should be pushed from one edge of the pavement to the center, and there lifted over any mortar that has been piled up. The straightedge should then be pulled back and any extra mortar wasted over the form.

Finishers must not be allowed to throw water on the surface of the pavement to make their work easier. Addition of water causes scaling and very rapid wearing away of the surface under traffic. A wood straightedge wears down unevenly and should be checked daily against the master straightedge. If not perfectly straight, it can be trued up with a carpenter's plane.

In case a high spot cannot be cut down with the straightedge, a heavy smoothing lute should be used to remove the extra material. A paddle float* is not to be used for this purpose. It is intended only to float small surface areas needing repair.

Finishing Joints

55. The finishing of the joints has an important effect on the pavement's riding qualities. The way the joints are made also affects the maintenance costs. Every longitudinal and transverse construction joint should have a uniform width of 1/4 inch. This width gives enough room for the joint sealer without causing a bump. Each transverse expansion joint should have a uniform width of 3/4 inch. All joints are to be rounded off at the surface of the pavement with an edger having a 1/4-inch radius. All joint finishing must be done with the concrete that is in place at the joint. The Inspector must not allow the use of extra mortar to make the job easier. Coarse aggregate must not be taken out and the holes filled with mortar. This use of mortar often causes spalling. Like other finishing operations, joint finishing must be done at the right time. Waiting too long, before removing joint shields and finishing, will result in a bad joint. Any extra material removed from any joint during finishing operations must be wasted outside the forms. If it is spread over the surface of the concrete near the joint, a poor riding surface will result. The Specifications require that all joint finishing be done from bridges and this requirement should be enforced at all times. After being finished, each joint must be checked along its entire length with the 4-foot straightedge placed across the joint. Any extra concrete or mortar must be cut off and wasted. Pushing down a high spot with a paddle float will not make a smooth riding surface.

The Inspector must pay particular attention to the finishing and straightedging of the joints made at the beginning and end of the day's work. The surface of the concrete placed on the day before should be cleaned carefully in order that a long straightedge can be used and the new slab can be made to join the old one perfectly at grade.

Belting (See VII - 32H)

56. After the surface of the pavement has been given a true surface by straight-edging, the final finish is obtained by belting*. This operation usually is delayed until most of the water sheen has disappeared. The purpose of belting is to remove any extra water and give the surface a uniform and slightly gritty finish. If it is done at the right time, it helps to prevent hair cracking. Different kinds of belts, which may be operated either by hand or by machine may be used. Requirements are detailed in the Specifications.

Belting is done most often with a burlap drag. This can be made by fastening a double thickness of clean burlap to a stick, or pole, which is at least 2 feet longer than the width of the lane. The burlap must be saturated with water before using and must be kept clean and wet. In use, the pole is held by a workman on each end so that it is about 2 feet above the pavement. It is slowly moved ahead while at the same time it is moved back and forth with a crosswise motion. This operation should be repeated until the surface is uniformly smooth.

As soon as the burlap gets dirty, or any set-up mortar clings to it, a new piece must be used. When the drag is not in use, the best way to store it is on a rack fastened to one of the bridges. The rack must be high enough to keep the burlap off the pavement.

Edging (See VII - 32G)

57. Rounding of the pavement surface at its outside edges with an edger having a 3/4-inch radius should follow the belting. The concrete should have reached such a degree of set that the edges will not slump after they have been finished. A trowel should be run along the edge of the pavement to free the concrete from the forms and push back the coarse aggregate. Doweled longitudinal joints must be opened 50 feet in advance of the edging. When the edger is being used, the leg between the concrete and the forms should be held vertically against the form at all times. If the edger is tipped so that the bottom of the leg is away from the form, the pavement may spall at the edge.

Usually, the outside edges of the pavement are to be finished to a 3/4-inch radius. Where the pavement edge meets a curb, gutter, concrete apron or another paving lane, the radius must be reduced to 1/4 inch.

Any marks left on the surface by the edging tool must be removed by a wet paint brush or a small piece of wet burlap.

Marking Date of Placing Concrete

58. At the beginning of each day's work the Mixer Inspector must mark the corner of the first slab constructed that day. This marking is done by scratching an arrow (showing the direction of paving),

the date, and the station number, in the surface of the concrete. The numbers should be 2 inches high and should be scratched deep enough with a sharp point, such as a pencil or nail, so they can be easily read and will not wear off.

Mixer Inspector's Records, Form 4220

59. On the Batcher-Mixer Slip, Form 4220, the Mixer Inspector must record the results of all slump tests, tests for percent of entrained air, and tests made for weight per cubic foot of the concrete (if made).

Mixer Inspector's Records, Form 472

60. The Mixer Inspector's Daily Record Book, Form 472, is a complete and permanent record of every day's paving operation. The keeping of a neat and accurate record is one of the most important jobs a Mixer Inspector has to do. When the job is finished, this record will tell anyone that is interested the whole story, in detail, of everything that went on. It is used to: check test results; find the reason for any pavement failures that might happen later; help settle any claims that the Contractor might make; and to serve many other purposes.

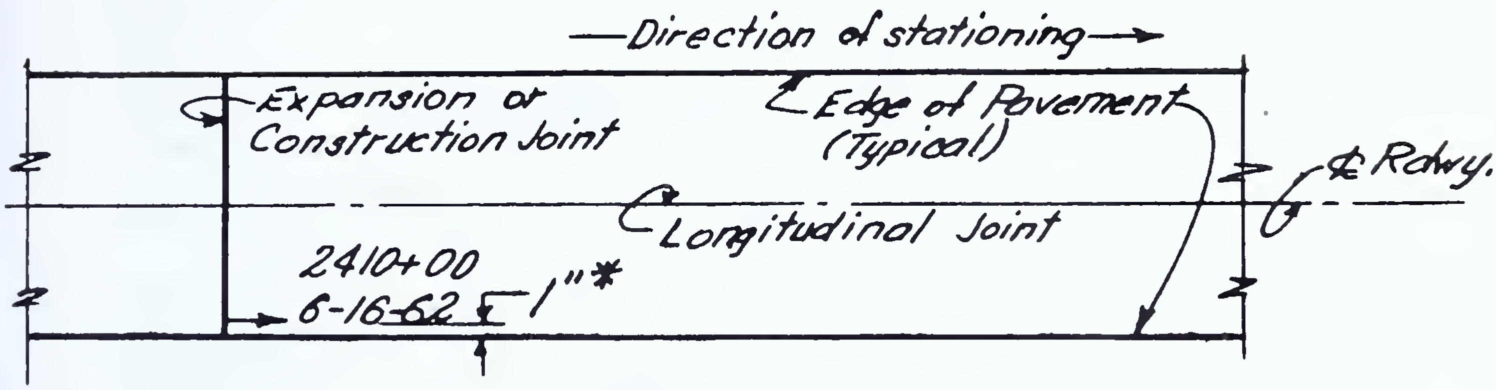
60a. At the top of the form are spaces for a summary of the day's work. This summary must show the date; the name of the Mixer Inspector; the time the mixer was started and stopped; how many batches were used, and if any were wasted; where on the job the day's work was done (by stations); a description of the lane; and the meter reading at the start and end of the day's work.

60b. Below the summary are spaces for recording the details of the day's work. These details give information on the batching of the concrete; the amount of concrete placed; and the weather. How to get this information is described below.

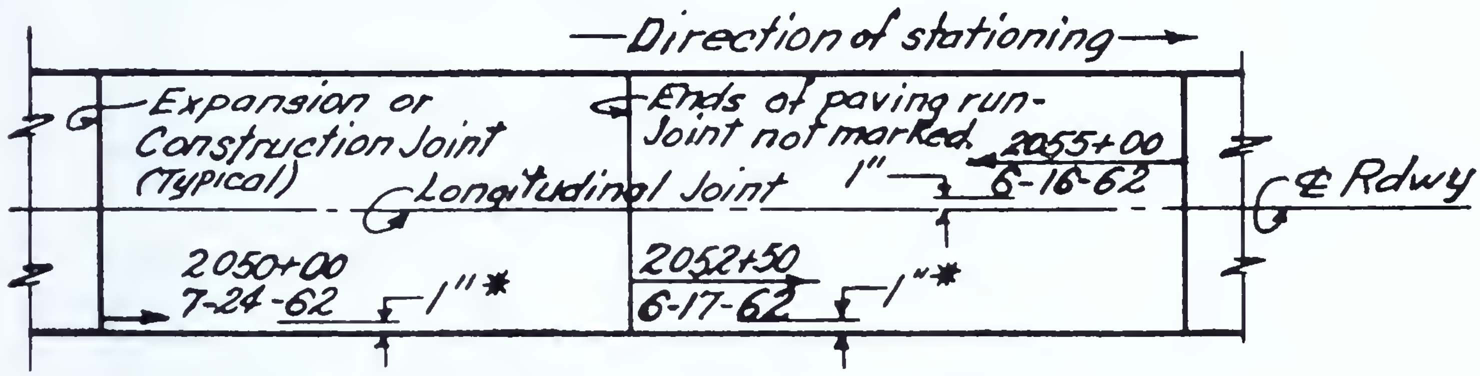
The number of Bags per Batch is the number of bags of cement used in each batch of concrete. This number depends on the mix design, the rating of the mixer, and the percent grade of the pavement. The number of bags is found by dividing the weight of cement shown on the Batcher-Mixer Slip by 94, (there are 94 lbs. of cement in each bag).

The Cement Factor is the number of bags of cement used in 1 cubic yard of concrete. This figure is taken from the approved mix design form for the job. A copy of this form should be at the Field Office and at the Batch Plant. For paving work, the cement factor is usually 6.25.

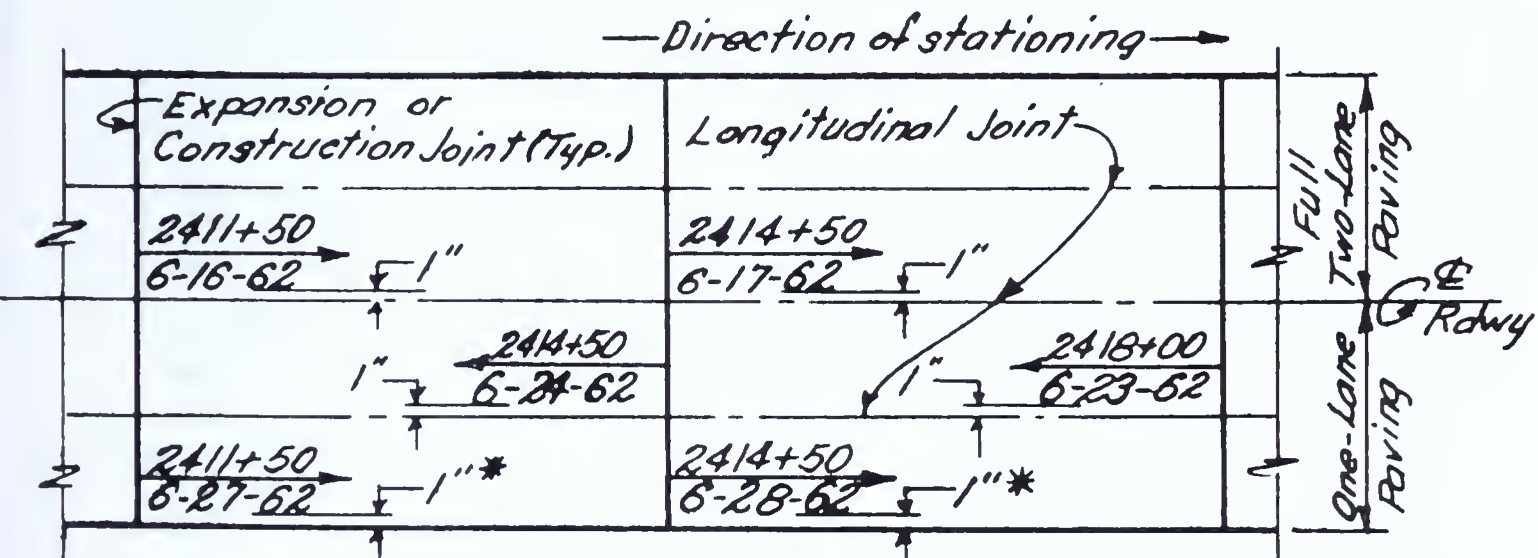
STANDARD METHOD OF MARKING DATE AND
STATION OF PLACING CONCRETE PAVEMENT AND BASE



FULL-WIDTH



FULL-WIDTH AND PART-WIDTH



* means "from edge of radius"

MULTIPLE-LANE

Date and arrow to be placed at the beginning of day's run.
Arrow to show the direction of paving.
Figures, 2 inches high, to be placed on right side of width poured, looking in the direction of stationing.
Full-width construction: Date to be placed on line with arrow, and station number above date.
Part-width and multiple-lane construction: Station number to be placed above arrow and date underneath.

Note: On the concrete base for an asphalt pavement show information only on header curb where one is used.

The Meter Reading is the number shown by the Batch Meter at the time of reading.

The Meter Batches is the number of times the meter has been tripped by the skip during a period of time. This number is found at any time, by subtracting the meter reading at the start of the day's work from the reading at the time of recording. This is most important at the end of the day's work.

The Correction space should show any number that must be added to, or subtracted from, the Meter Batches to get the number of batches actually mixed. For instance, if the empty skip is raised far enough to trip the meter, one batch will have to be subtracted from the Meter Batches. Whenever the meter is read, a check should be made with the mixer operator to find out if any batches shown by the meter were not actually mixed.

The record of Wasted Batches shows the number of batches that were dumped from the batch trucks but not used. These are batches that were thrown away because they did not meet the Specifications; either they were too wet or too dry, or two batches of material were dumped into the skip at one time, or they were not satisfactory for some other reason.

The record of Used Batches shows the number of batches which met the Specification requirements and were actually used in the pavement.

The record of Plant Batches shows the number of batches dumped into the skip. This number is equal to the number of Wasted Batches plus the number of Used Batches. It is the number of batches recorded at the Plant.

The record of Lin. ft. placed shows the length of the pavement placed during the day's operation. It is only entered for Total and not for each time period. This length is measured by flat chaining. On tangents, the length of the day's run may be found by measuring along the forms. On curves, the measurements must be made along the centerline of the pavement for two-lane paving, and on the centerline of the lane for one-lane paving.

The record of Sq. yds. placed shows the total number of square yards placed during the day's work. It is only shown for Total and not for each time period. It is found by multiplying the Lin. ft. placed by the width of the paving (in feet) and then dividing by 9, (there are 9 square feet in 1 square yard). For example, if the length of a 12-foot lane placed during the day was 300 ft. (Lin. ft. placed), the number of Sq. yds. placed would be:

$$\frac{300 \times 12}{9} = 400$$

In case any part of the paving had a different width, the average width for that part must be found. For example, if the width changed from 12 feet to 18 feet in a length of 300 feet the average width is $\frac{12 + 18}{2} = 15$ feet, and the number of Sq. yds. placed would be:

$$\frac{300 \times 15}{9} = 500$$

This number should be added to the number of sq. yds. of regular pavement placed the same day and the total recorded.

Instead of the Act. lbs. used (weight of the cement) it is the usual field practice to record the number of bags of cement used. This figure is found by multiplying the Used Batches by Bags per Batch.

Instead of the Theo. lbs. used, the theoretical number of bags used is usually recorded. This is the number of bags of cement that would be used if all quantities and proportions of materials in each batch were exactly the same as in the mix design, and the pavement was built exactly to the width and thickness as shown on the Plans. Generally, there are two cases involved in getting this figure, and there is a different way of handling each case.

Case 1. If the width of pavement remains the same. The Theo. bags used is found by multiplying the Lin. ft. placed by a "yield factor". This factor is the number of bags of cement needed in 1 foot of lane and is equal to the part of 1 cubic yard of concrete, needed to build 1 foot of lane, times the Cement Factor. For example, if the lane is 12 feet wide and 10 inches thick, the number of cubic feet in 1 foot of lane would be

$$12 \times \frac{10}{12} \times 1 = 10 \text{ cubic feet,}$$

which is equal to 10/27 of a cubic yard. If the Cement Factor is 6.25, the "yield factor" would be

$$\frac{10}{27} \times 6.25 = 2.31 \text{ (bags of cement for every linear foot of lane)}$$

If the Lin. ft. placed during the day was 600, the Theo. bags used would be

$$600 \times 2.31 = 1386.$$

Case 2. If the width of pavement is not the same from start-up to the end of the day, due to widening, paving intersections, or any other reason. The Theo. bags used is found by multiplying the Sq. yds. placed by the slab thickness, in fractions of a yard (a 10 inch slab would be 10/36 yard thick), and by the Cement Factor. For example, if the slab

thickness is 10 inches, the Sq. yds. placed was 500, and the Cement Factor is 6.25, then the Theo. bags used would be

$$500 \times \frac{10}{36} \times 6.25 = 868$$

The Overrun % is the percentage recorded when the Act. bags used is more than the Theo. bags used. This percentage is the difference between these numbers, divided by the number of Theo. bags used, and multiplied by 100. For example, if the Act. bags used was 1415 and the Theo. bags used was 1386, the Overrun % would be

$$\frac{1415 - 1386}{1386} \times 100 = 2.1\%$$

On most paving jobs the overrun should be about 2 percent. This amount of overrun is due to mortar wasted over the sides of the forms, mortar worked into the subbase, concrete shrinkage, and other usual losses. If the overrun is much more than 2 percent, some of the things that could be wrong and which should be checked are:

1. The pavement is too thick because the surface of the subbase was too far below the tops of the forms.
2. There is less entrained air in the concrete than called for by the design.
3. The aggregate weights were based on a too low moisture content.
4. The batcher scales were not accurate or some aggregate hung up in the weigh hopper.
5. Wrong batch weights were used.

The Underrun % is the percentage recorded when the Act. bags used is less than the Theo. bags used. It is figured the same way as the Overrun %. For example, if the Act. bags used was 1374 and the Theo. bags used was 1386, the Underrun % would be

$$\frac{1386 - 1374}{1386} \times 100 = 0.87\%$$

If there is any Underrun % something is seriously wrong. Some of the things that could be wrong and which should be checked are:

1. The pavement is too thin because the surface of the subbase was not far enough below the tops of the forms, or the forms were pushed down by the equipment.
2. There is more entrained air in the concrete than called for by the design.
3. Aggregate weights were based on a too high moisture content.
4. The batcher scales were not accurate.
5. Wrong batch weights were used.
6. Too much water was used for mixing the concrete.

The R.P.M. Mixer is the record of the speed of the mixer drum in revolutions per minute. It is the number of complete turns the drum made in 1 minute.

The Time Batch Mix for a single-drum mixer is the record of the number of minutes all the materials for a batch of concrete were in the drum. In the case of a dual-drum mixer with a rating of 1 cubic yard, or less, the transfer time required for the batch to pass from one drum to the other, should not be included. If the rating of a dual-drum mixer is greater than 1 cubic yard, the transfer time is included.

The Weather record should describe any condition that could affect the finishing and curing of the concrete, such as:

Dry - windy	Light rain
Wind - dust	Heavy rain _____to_____
Damp, or humid	(time of start and stop of rain)

The Temperature Range record should be based on the actual temperatures, measured in the shade with an accurate thermometer, at the beginning and end of the working day, and also, the highest and lowest temperatures read during the day. When the temperature is below 50 degrees F. readings should be taken at least 4 times during each day.

The Theo. Water pr. bag is the number of gallons of water per bag of cement called for by the mix design.

The Act. Water pr. bag is the record of the number of gallons of water actually used per bag of cement. It should be within 0.2 gallons of the amount shown on the Batcher-Mixer Slip in use during each time period.

60c. The Daily Record page of Form 472 also has spaces for recording test data obtained by the Slump Test and Air-Entrainment Test. There is enough space under Slump Test for recording the results of slump tests made at 10 different times during the day. The result which is written in the book should be the average of the three tests which were made at the time shown. For example, if concrete is taken from the pit*and 3 slump tests made, the results might be: 1-1/4 inches; 1-3/4 inches; and 1-1/2 inches, This is the same as 5/4; 7/4 and 6/4 inches. When these are added, the result is 18/4. If 18/4 is divided by 3, the result is 6/4 and is equal to 1-1/2 inches, which is the average value that should be recorded.

A set of 3 slump tests should be made whenever a Batcher-Mixer Slip is received. A set of 3 tests also should be made whenever the consistency of the concrete changes, that is, if it spreads out more, or less, when dumped from the mixer bucket. At least 3 sets of 3 slump tests each should be made during the day.

The Air-Entrainment Tests must be made often enough to make sure that the percent of entrained air is within the specified limits and that it does not change during the day. At least three air tests should be made daily. If the concrete starts to bleed during finishing, or there is a change in workability, more tests should be made.

60d. Under Cement Used, the Mixer Inspector should put the information as to the car numbers, car initials, number of bags (instead of pounds), and the manufacturer's name, he gets from the Plant Inspector. The location and the lane should be recorded in the last two columns.

60e. Under Paver Delay must be shown any time periods, lasting more than 5 minutes, when the mixer was idle, and the reasons for delay, such as: no batch trucks; mechanical breakdown; no water; etc.

60f. The Wire Mesh Check space is for recording the depth from the pavement surface to the wire mesh, which should be measured and recorded at least three times each day. At the station where the measurements are made, the depth should be measured at several places across the lane, and the results averaged.

60g. Under Structures should be recorded the location (by station) and type of any structure, and the class and amount of concrete used in that structure.

60h. Under Remarks should be recorded briefly, any important instructions given to the Contractor's representative, or anything unusual having to do with the construction work.

60i. Under Official Visits should be recorded any visit made by an Engineer above the grade of Inspector-in-Charge, the Engineer's name and the approximate time of his visit. Also, the Engineer should be given the Record Book and asked to make a note of his visit and confirm any verbal instructions in writing in the space under the heading of Inspection in the back of the book.

Initial Curing of Concrete Pavement (See VII - 47A)

61. After the concrete has been placed and finished, as required by the Specifications, it must be cured by keeping it warm and moist until it has gained its full strength. The curing of the concrete also has a great effect on how long the pavement will last. When concrete sets, it has many very small holes and channels which are filled with the mixing water. If it is kept moist, the water acts on the cement to form a jelly-like substance, called "gel", which partly fills these holes and channels and binds the pieces of aggregate together. Once the concrete has dried out, the forming of this gel stops. The longer the concrete is kept moist by curing, the greater will be the

amount of gel formed and the better the concrete will be. It will be stronger and will not wear down so much from chains on car wheels as it would if it had been allowed to dry out too soon after being placed. Any delay in starting curing, especially in hot or windy weather, can cause surface cracking of the concrete.

Because of the great importance of curing in getting good concrete, the Inspector should check this operation at least once an hour during the day. As soon as the finished surface can be covered without marring it, wet burlap should be placed on the pavement and kept saturated for 24 hours. The burlap must be laid so as to have a double thickness at all points. One way to do this is to overlap each piece for half its width on the piece already placed.

Burlap is required for initial curing because it can be placed earlier than some other covering materials without seriously damaging the finished surface of the pavement. Also the saturated double thickness holds water which can be absorbed by the concrete during the early stages of curing, which helps to insure getting a surface that will not wear easily.

The curing always must take first place. If there is not enough labor, or enough water, to take care of both the paving and the curing, the paving must be held up until the curing is attended to. Arrangements must be made so to have the curing continued on holidays, or at any other time when paving is interrupted, except in rainy weather.

When there is any possibility that the air temperature may drop below 50 degrees F. during the next 24 hours, the special requirements of the Specifications for curing during cold weather must be met.

Removal of Forms

62. The Specifications require the side forms be left in place at least 24 hours after the concrete has been placed. This requirement must be enforced rigidly since the forms protect the concrete, which does not yet have much strength. They also prevent the escape of moisture from the edges of the pavement during the important first part of the curing period. For this reason, form pins should not be removed, and forms should not be "loosened" until the end of the specified period.

When the forms are being removed, care must be taken never to pry against the slab or to throw pins, or sections of the form, onto the new concrete. Form pins should be pulled with equipment that works outside the forms and does not put pressure on the edges of the slab. If forms have been properly cleaned and oiled, it should be easy to remove them. In all cases, the sections of form must be pulled away from the edge of the slab without prying against the concrete.

Any honeycomb along the edges of the pavement slab must be repaired with a mortar containing one part cement and two parts of sand, by volume. This repair work should be done promptly after removal of the forms in order that the edges of the slab can be protected from loss of moisture. If it is found that honeycomb always appears at certain points, such as where transverse joints butt against the form, more attention must be given to these places during future work.

After the forms are taken off, any concrete at the ends of transverse joints must be removed. The metal plate or expansion-joint material must be exposed for the full depth of the slab.

Daily Check of New Pavement

63. When the concrete has hardened enough that it can be walked on without marring it, all the burlap used for initial curing must be removed from short sections of the pavement at a time so the surface can be tested with a straightedge, as required by the Specifications. The concrete must be covered up again before the surface dries out and the curing is interrupted.

This inspection must be made daily so that the Inspector-in-Charge will know if the pavement constructed the day before is satisfactory. If the straight-edging and general inspection show that the workmanship does not meet the Specification requirements, the Contractor's representative must be notified promptly and a report made to the Assistant District Construction Engineer. From what he has seen of the concrete placing and finishing operations, the Inspector should be able to decide on the cause of the trouble, such as, non-uniform concrete, form settlement, improper adjustment of the finishing machine, or poor workmanship by the finishers. He should see to it that the work is done right the next time.

The smoothness of the surface is usually tested with a 16-foot straightedge, but a 10-foot straightedge should be used on vertical curves. Each straightedge must be checked and approved. The straightedge always is laid parallel to the sides of the lane in several locations, from one side of the lane to the other. It must be held in each position long enough for the Inspector to make a thorough examination along its entire length. He should stand on the side away from the light, and look for points where it does not touch the pavement. If at these points, the distance between the straightedge and the pavement is more than 1/8 inch (the thickness of a penny placed on top of a nickel), he should locate and mark the high point, or points, that hold the straightedge up.

After the lane has been checked from one side to the other, the straightedge should be moved ahead half its length and the operation repeated. The entire area of the pavement must be checked in this way. The District Engineer may let the Contractor correct small bumps by

grinding down the surface, but, if found necessary, any section of pavement with high spots of more than 1/4 inch must be removed and replaced at the Contractor's expense, as required by the Specifications. Everyone concerned should be told immediately about anything that is wrong with the pavement. Decisions in such matters must be made promptly and before the concrete has hardened too much and cannot be removed easily.

At the time the straight-edging is done, all joints must be inspected, and any mortar bridging* the joint opening must be removed.

Whenever any hair cracking* can be seen on the surface of the pavement, the Inspector-in-Charge must report what has happened to the District Engineer. This report should state whether the cracking took place during finishing of the concrete, or was noticed later. It must include information about the materials used in the concrete; the temperature of the concrete when placed; the condition of the concrete while being finished; the method of finishing; the range of the air temperature and the weather conditions during finishing and curing; and the method of curing. The report also should describe what has been done to prevent the cracking from happening again.

Continued Curing of Concrete Pavement

64. After the surface of the concrete has been kept moist for 24 hours by the initial curing, the Specifications require that the curing be continued for an additional 72 hours in normal weather. Since it may not be practical to keep burlap saturated continuously for a long time, other methods, such as paper coverings, are usually used for continued curing. The details of several methods are described in the Specifications. In any case, the objective is to put as nearly an air-tight seal as possible over the exposed surfaces of the concrete and to prevent the escape of any water vapor. During the curing period, the concrete will gain strength rapidly if it is kept moist.

Paper covers used for continued curing are made of two sheets of paper cemented together with a bituminous cement in which fibers are placed to give greater resistance to tearing. One of the sheets is bleached to a light color. The paper should always be used with this sheet up so as to reduce heating of the pavement and evaporation of moisture by the sun. The Specifications require that the covers must be between 20 and 75 feet long. Pieces shorter than 20 feet must be cemented together with a lap joint at least 4 inches wide. There must not be any holes or rips in the covers that would permit water vapor to escape.

All surfaces to be covered should be wet before the paper covers are placed. If any concrete surfaces (including the edges of the slab) have dried out since the removal of the burlap or forms, they should be rewetted.

Immediately after removal of the saturated burlap, stringer strips, at least 24 inches wide, are first placed on the surface of the pavement along each edge. The larger pieces, of a width which will cover the surface of the pavement from edge to edge, are then unrolled from a pole or a piece of 2 x 4 inch piece of lumber and placed on the pavement surface and on the stringer strips. Placing must be done carefully so that the surface of the pavement is not marred.

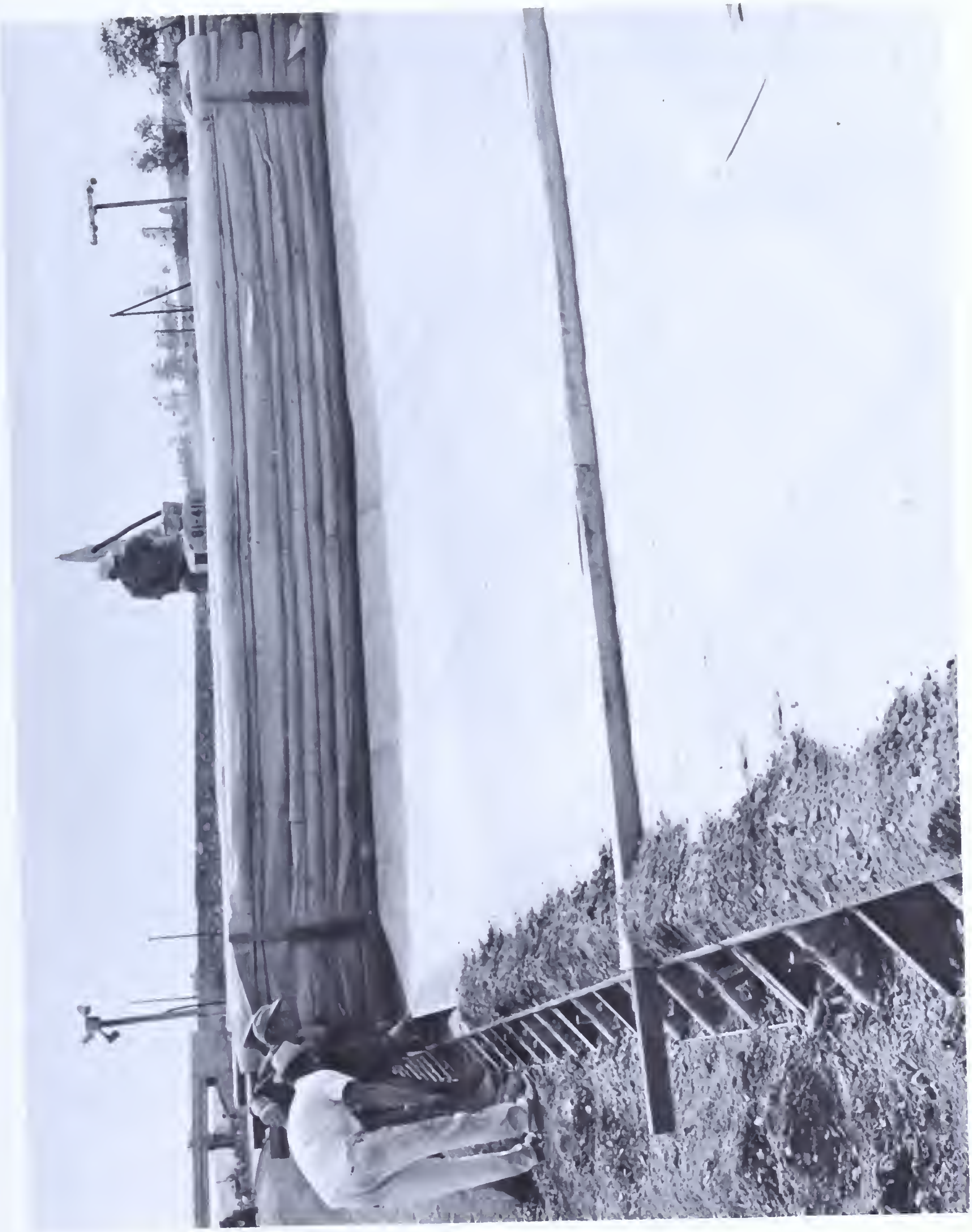
Adjoining covers must overlap at least 12 inches and the lap must be weighed down tightly so that no moisture can escape. Immediately after placing the covers the edges must be held down by placing a continuous row of approved material on the edges of the covers just inside the forms. Enough weight must be used to prevent the edges and laps from being lifted and the covers displaced by high winds. An air-tight seal must be maintained at all times so that water vapor formed by the heat the concrete produces as it gains strength, will not escape.

Immediately after the forms are removed any small honeycombed areas should be patched with a mortar made with one part of cement to two parts of sand. This is done so that the patching mortar will bond firmly to the "green" concrete* and will be properly cured by covering with the stringer strips. This patching should be done as rapidly as possible so that the edges of the pavement slab do not dry out. If there is delay between removal of the forms and covering the edges of the slab with the stringer strips, the exposed concrete surfaces should be inspected and, if not moist, should be rewetted.

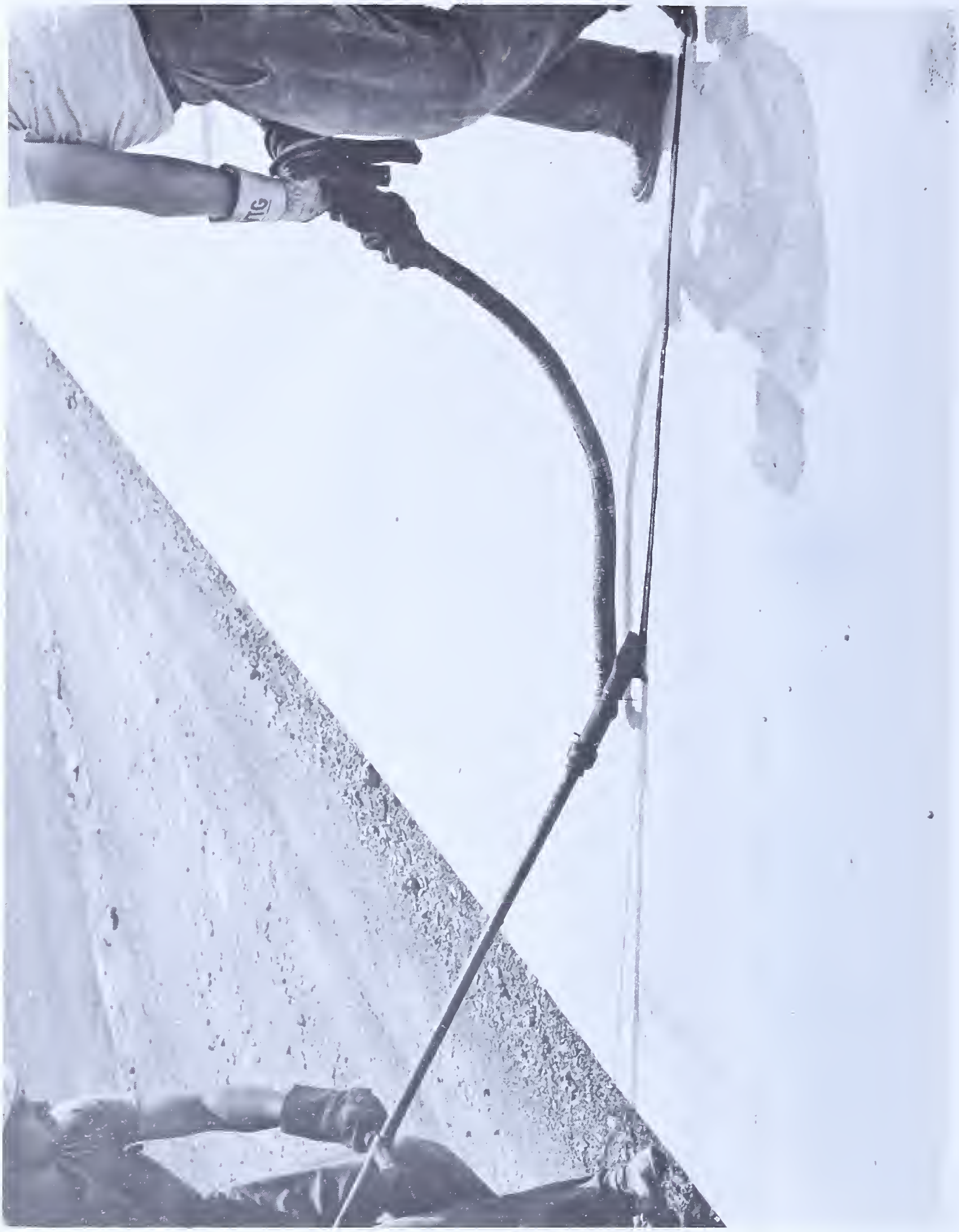
The stringer strips then should be pulled out over the edges of the slab, carried down to the bottom of the pavement and secured in place with a continuous bank of earth.

After the paper covers have been in place for about 24 hours a spot check should be made to see if they are keeping the concrete in a moist condition. One of the laps should be temporarily loosened and the end of the cover raised so that the surface of the concrete can be inspected. If the surface appears dry, the Inspector-in-Charge should be informed.

When membrane curing is permitted, the entire covering should completely seal in the water vapor*. The membrane material contains a solvent which evaporates quickly, and the type used for highway work usually contains a white colored pigment. The white color reflects the rays of the sun and prevents them from heating the concrete. This reflection lowers the curing temperature and makes it easier to prevent the escape of water vapor. If the membrane material does not contain pigment, it usually contains a dye so the compound may be seen on the surface of the concrete. Some of these dyes are called a fugitive type, which means that they bleach out quickly after the membrane material is sprayed on the concrete.



Initial Curing



Sealing Joint

Sawed Joint

Sawed Joint

Some of the materials in membrane curing compounds tend to settle out during storage. If stored materials are not remixed, the membrane will not do the job. Unless the drum of material has an agitator, it should be turned end-for-end several times and rolled at least 100 feet to mix the contents before use. Agitators must be operated long enough to mix the contents thoroughly. A 1 quart sample of the material from each shipment should be sent to the Laboratory. It is important that the material in the drum be thoroughly mixed before the sample is taken.

The surface of the concrete should be moist, but free from standing water, when the membrane material is applied. If the surface is too dry, the solvent will be absorbed and a tight membrane will not be formed. Enough membrane material must be applied to do the job and the material must be applied uniformly. At least the amount called for by the manufacturer should be used. It is often necessary to use more membrane material in order to get a seal that will prevent the loss of water vapor. The area covered by each drum of material should be measured to make sure that enough is being used. For highway work the material usually is applied by spraying-machines which do two coats in one pass of the machine. When a hand sprayer is used, two coats of material must be applied. For the second coat, the sprayer should be moved in a direction at right angles to that for the first coat.

In any case the membrane material must be applied evenly and must form a continuous film that leaves no part of the concrete exposed. The film must be free from pin holes or other openings through which water vapor can escape. The sides of the slabs should be sprayed with small hand sprayers as soon as the forms have been removed and any honeycomb repaired. Care must be taken to cover all parts, including the upper sides of keyways.

The membrane material will interfere with the bond between joint-sealing materials and the concrete. All unpoured joints must be protected when the spray is being applied. They may be protected with paper tape, which also prevents loss of moisture during curing.

After a satisfactory coating of membrane has been applied, it must be protected. Walking on the membrane, operating equipment on it, or doing anything else that will scrape off, or wear off, the membrane will break the film and let water vapor escape. Any area where the membrane has been damaged by rain, has been scuffed off, or has pinholes, must be resprayed. A continuous film must be maintained at all times.

If the Inspector believes the membrane is not preventing the escape of water vapor, he should make a field test. A small dish, or the cover from a tin can, is placed on the surface of the concrete and a few crystals of calcium chloride placed in the dish. The next step is to cover the dish with a larger glass dish, turned upside down, and seal the edges of the large dish on the pavement with putty. Another way

of making a cover is to form a rope, about 3/4 inch in diameter, out of putty. Place this rope around the small dish, in a circle with a diameter of about 8 inches, then press a piece of glass, 10 inches square or larger, down on top of the putty. The calcium chloride crystals should be examined from time to time through the glass cover. If they start to dissolve at the sharp edges of the crystals, water vapor is escaping from the concrete through the membrane. When this happens, another coat of the membrane material must be put on.

Protection of Pavement

65. The Inspector must see to it that the pavement is protected at all times from both damage and traffic. During construction, barricades must be placed on the pavement at the ends of the section under construction and at any intersecting roads. At night all barricades must have enough flares, blinking lights, or reflectors, so drivers can see them, even in rainy or foggy weather.

If a section of pavement is opened to traffic before the contract is completed, each section must be protected by a temporary concrete header, or by double 2 x 6 inch planks placed on edge against the end of the concrete slab.

Temporary Shoulders

66. When permanent shoulders have not been constructed in advance of the paving, temporary shoulders should be constructed wide enough to protect the traveling public; to protect the edges of the pavement from mechanical damage; and from undermining by water running off or along the edges of the pavement.

The Contractor is not permitted to construct this shoulder from material excavated in the shoulder area below the ditch line. The material must not have large stones, broken concrete, or other material that would nest together and allow water to run through it.

Sawed Longitudinal Joints (See VII - 47C,D)

67. When two-lane pavement is constructed full width at one time, the steel tie bars between the two lanes are placed as required by the Specifications. A continuous groove for the center joint later is sawed into the concrete. The saw may have either an abrasive blade or a diamond blade, but the groove must be at least 3/16 inch wide and 2-1/4 inches deep. Diamond blades are preferred for sawing pavement, because an abrasive blade usually should be used as soon as the concrete has hardened enough to prevent spalling; this early sawing may interfere with curing. If an abrasive blade is used, the depth of the cut should be checked frequently, because it becomes less as the blade wears. Sawing with a diamond blade may be delayed for 7 to 21 days after the

concrete has been placed. The depth of cut is quite constant once the machine has been set correctly.

The width of cut should be checked frequently with a gage made from a piece of metal 3/16 inch thick. The groove must be cut to the full specified width so the joint-sealing material can be poured to the full depth of the cut. Full width of cut also makes sure that there will be enough joint-sealing material in the joint to allow it to stretch if the joint opens. A sawed joint should be flushed out with water immediately after it has been cut. If this is not done the grout formed by the sawing will harden and its removal will be very difficult. When a sawed joint is to be sealed immediately, it should be blown out, and dried out, after being flushed, with a jet of compressed air, and heat if necessary.

If dirt gets into a sawed joint before it is sealed, or if the joint was not fully cleaned in the first place, it may be necessary to run a saw through the joint again, then repeat the flushing, blowing out and drying. A special saw, with reversed rotation, sometimes is used for cleaning.

All joints must be clean to the full depth before the sealing compound is poured into them.

<u>Sealing Joints</u> (See VII - 47B)

68. Before any traffic is allowed on the pavement, including hauling by the Contractor, all the joints in the pavement must be sealed as required by the Specifications. The joint sealing material must be of the specified rubberized type.

The sealing material has two jobs to do. It must prevent water from getting into the joint and it must also keep out small stones that would wedge the joint and cause spalling. To keep out water the sides of the joint must be dry, but not dusty, or the sealing compound will not stick to the concrete and make the joint watertight. The joint must be filled completely, <u>from the bottom up.</u> If any space is left at the bottom, the sealing compound will settle later and stones may get into the joint at the top. These stones can cause spalling of the concrete when there is movement at the joint.

Rubberized sealing compounds are very sensitive to high temperatures and are ruined quickly by overheating. The danger of overheating is especially serious at the start of melting the material. The compound next to a hot surface may reach a very high temperature quickly and be spoiled. Specifications make it necessary that the melting kettle be a double boiler which is gas heated, and of the indirect heating type, and oil be used to transfer the heat from the fire to the compound. The kettle must have a mechanically operated agitator and a positive thermostatic temperature control. The controls should be set so no

portion of the sealing compound will be heated to more than 450 degrees F. The temperature should be checked with an accurate thermometer. After heating is started, the compound must be stirred continuously with the mechanical agitator.

Before the compound is placed in the kettle, all of the bag must be removed, and the compound broken into small pieces with an ax. When starting to heat the compound only a few pieces should be put into the kettle. After these pieces have melted, other pieces may be added gradually. The material in the kettle must be stirred at all times. As heated compound is drawn out of the kettle more pieces should be added to keep the level in the kettle nearly constant.

In case pouring is delayed, the temperature of the material in the kettle should be reduced to 275 - 325 degrees F. until shortly before pouring begins. The material must not be left in the kettle overnight. Any material left in the kettle at the end of the day should be drawn off into bags like the original containers. These bags can be had from the manufacturer of the compound.

After the joints have been cleaned out, the dust must be blown out by a jet of compressed air. The air compressor should be of the type that will maintain 90 pounds per square inch (psi) air pressure. The joints should then be checked to see that the inside surfaces are dry. If the inside surfaces are moist, the compound will not stick to the concrete. Also, the moisture will be turned to steam by the heat of the compound, and the compound will bubble and blister.

The inside surfaces of a joint may be dried by use of a gas-fired, or oil-fired, torch and the compressed air jet. The torch must not be kept in one place long enough to damage the concrete. As soon as the inside surfaces of the joint are warm, the moisture should be blown out with the compressed air jet. These steps may have to be repeated to get the inner surfaces perfectly dry.

As soon as the joint is clean and dry, its ends should be blocked to prevent loss of the sealing compound. For this purpose, a piece of wood lath may be held in place by a stake driven opposite the end of the joint close to the edge of the pavement. The stake is driven down flush with the surface of the pavement, and then a piece of lath about 4 inches long is driven down flush between the stake and the pavement to seal tightly the end of the joint.

The compound must be placed in the joint in two pourings. The first pouring should fill the joint to about one-half to two-thirds its depth. As soon as this material has cooled and shrunk, the second pouring should be made. The second pouring must be made within one hour of the first. It should bring the sealing material flush with the surface of the pavement. If the top of the sealing material is more

than 1/8 inch below the surface after it has shrunk, an additional pouring is required. To find if there is space at the bottom of the cut, probe the filled joint with an ice pick or knife blade. Any joint-sealing material above, or on, the surface of the pavement can be removed by means of a long handled, chisel-edged scraper, which is kept hot with a torch. The material that is scraped off must be thrown away.

If the compound in the pour pot becomes too cold to be poured or to flow to the bottom of the joint, it must be returned to the kettle and reheated. The use of hand pouring pots is permitted, but they must be kept clean in a way that is approved by the District Engineer. Burning them out or using gasoline or other solvents to clean them is <u>not</u> permitted.

<u>Operating Equipment on Pavement</u>

69. Concrete does not reach its full strength for a month or more in warm weather and a much longer time may be needed in cold weather. If heavy loads get on the pavement before it has gained enough strength to support them, it will be ruined. The pavement may show visible cracks, or it may be weakened by very small cracks which can not be seen at first. For this reason, no heavy equipment of any kind must be permitted to stand on, operate on, travel along, or cross the concrete pavement until the concrete is at least 10 days old if regular cement was used, or 3 days old if high-early strength cement was used.

In any case, beam tests on the concrete must show that the concrete has the necessary strength and Form 458-B must have been received from the District Engineer, before equipment or traffic is allowed on the pavement. After the concrete has become strong enough to take the load, the Contractor may get permission to operate the mixer on the pavement in the case of part-width or extra-width paving. This permission must be received from the District Engineer in writing before the equipment is moved onto the pavement.

After permission has been obtained to operate the mixer on the pavement, the surface must be protected from scuffing or abrasion by wood mats at least 2 inches thick or by fiber or rubber belting at least 1/2 inch thick. The belting must be at least 2 inches wider than the treads of the mixer. Once the mixer moves onto the pavement, it must operate and travel on the central part of the slab so the treads will be as far as possible from each edge. The edges and the corners next to joints are the weakest parts of the pavement.

The Contractor may be given permission to move a shovel of not over 2-1/4 cubic yard rated capacity under the same rules and provisions. However, this permission does not mean that the Contractor can operate the shovel while it is standing on the concrete.

The permission of the District Engineer to move equipment on the pavement applies only to sections of the project which have not yet been opened to regular traffic. When the Contractor moves equipment on a public highway he must obey the regular laws and regulations which cover such movements. Also, the Specifications place restrictions on the load the Contractor may haul over pavement on or connecting with the project. If the Contractor wants to haul heavier loads on the pavement, written approval of the District Engineer must be obtained.

Opening of Pavement to Traffic

70. Under no conditions should the new pavement be opened to traffic until the District Engineer has sent out written orders that it can be opened. When sections of the pavement are ordered to be opened to traffic before the project is finished, the Contractor must furnish signs, barricades, and lights, in accordance with the Specifications, to protect the rest of the pavement from traffic. In case traffic must cross new pavement that is not strong enough to take the loads, the Contractor must build a bridge over the pavement to protect it.

If regular cement was used, the pavement must not be opened to traffic or hauling until it is at least 10 days old and all joints have been sealed. In no case should vehicles be allowed on the pavement until the beam tests* show that the modulus of rupture* is at least 550 pounds per square inch when the beams are made, cured, and tested in accordance with the Department's procedures. The results of all tests are to be reported to the District Office on Form 458-A. The District Office will notify the Inspector-in-Charge when the pavement may be opened to traffic.

Tests for Thickness of Pavement

71. As described in the Specifications, cores will be cut from concrete pavement during construction or after completion. If the cores do not show that the pavement has the required thickness, the Contractor will be paid less money, or may have to take the pavement out and replace it. Also, the Mixer Inspector will be held responsible for any short cores. There is no excuse for thin pavement. It can be prevented by paying attention to subbase testing, form support, and finishing operations.

If, at any time during construction, there is any possibility that the construction and inspection procedures may not result in the correct slab thickness, a positive check should be made. A thin metal plate, about 18 inches square should be placed on the subbase. It may be placed in the exact center of the lane and marks made on the forms on each side so that the plate may be found after the concrete is placed. After finishing operations are completed, a thin metal rod, which is about 1/4 inch in diameter and has a sharp point, is worked down through the plastic concrete until the point touches the metal plate. A mark, or scratch, then is made on the rod, exactly even with the surface of the concrete. The measured distance from the point of the rod to this mark is the true thickness of the slab.

CHAPTER VIII

BITUMINOUS CONCRETE:

PLANT INSPECTION AND PLACING

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CHAPTER VIII

BITUMINOUS CONCRETE: PLANT INSPECTION AND PLACING

Materials for Bituminous Concrete

1. Bituminous concrete is a high type paving material very much like portland cement concrete, but the binder which holds the particles of aggregate together is a bituminous material*, usually asphalt. When asphalt is the binder, the material is called asphaltic concrete. Asphaltic concrete is a uniform mixture of graded coarse aggregate, graded fine aggregate, mineral filler, and asphalt cement.

Coarse aggregate may be crushed stone or slag, or crushed or uncrushed gravel. Fine aggregate is natural or manufactured sand. Filler is the part of the aggregate which passes a No. 200 sieve. It may be either the fines, or dust, in the aggregate or a commercial mineral product made by grinding some material, such as limestone, to a fine powder. To give satisfactory service, a bituminous concrete mixture must be both stable under traffic loads and durable, so that it will last a long time and not need a lot of maintenance.

Required Properties of Asphaltic Concrete

2. To be durable, an asphaltic concrete pavement, like a pavement of portland cement concrete with entrained air*, must contain the right amount of air voids.* It must also contain enough asphalt to bind the aggregate particles together firmly and to give the pavement some flexibility. If the mixture contains too much asphalt or does not have enough air, the pavement will be too soft or too plastic*. In hot weather, such a pavement will be pushed out of place by traffic. Waves in the pavement are sometimes caused by plastic flow where motor vehicles brake to a stop at a traffic light.

If there is too much air or the voids are too large, water will get into the pavement. Water may cause the asphalt to strip from (peel off) the aggregate. When this happens, the pavement is weakened, the aggregate may come loose, and the surface may ravel* under traffic. Potholes*, sometimes seen in an asphalt pavement, usually start with raveling of the mixture at the surface. If the mixture does not have enough asphalt, it will be hard and brittle, and the pavement will crack if the base beneath it is pushed down by heavy traffic. The mixture may also be brittle if the asphalt itself is too hard because it has been over-heated in the asphalt plant. Brittleness of the mixture may also result from too much air or too much filler.

Design of Mix

3. To be stable so that it will not move under the action of traffic, and to be durable so that it will not ravel or crack, an asphaltic concrete mixture must contain the right amount of asphalt. <u>Using the right amount of asphalt</u> is the most important factor in the life of an asphaltic concrete pavement. Too much asphalt will cause the pavement to push into waves (shove)

NOTE: Words marked with an (*) are explained in a word list at the back of this book.

under traffic. Either it must be removed, or the tops of the waves must be cut off. A pavement with too little asphalt will be brittle and will have cracks and potholes.

The amount of asphalt which is right for any particular asphaltic concrete mixture depends on a number of things. Two of the most important are the gradation of the aggregate and the amount of filler in the mix. When an asphaltic concrete pavement is rolled during construction and then compacted* more by traffic, the particles of aggregate are pressed together tightly. However, there are always spaces between them. These spaces are partly filled by the asphalt. There must be enough room between the particles of aggregate not only for the asphalt that is needed for durability, but also for unfilled space or the necessary voids*.

If the gradation* of the aggregate changes, the amount of space between the particles also changes, and a different quantity of asphalt is required for stability and durability. For this reason the Inspector must remember:

<u>ONCE THE RIGHT AMOUNT OF ASPHALT HAS BEEN SET FOR AN ASPHALTIC PAVING MIXTURE, THE GRADATION OF THE AGGREGATE MUST BE HELD AS CONSTANT AS POSSIBLE.</u>

The amount of mineral filler* also has a great effect on the stability and durability of asphaltic concrete. A change in the percentage of filler changes the amount of space between the aggregate particles more than does the same percentage change in the amount of aggregate of a certain size. Because it is so very fine, the filler has still another effect. A large amount combines with the asphalt to make a mortar, which becomes the binder holding the aggregate particles together. If there is too much filler for the amount of asphalt, the mortar will be less sticky and less flexible than asphalt. An asphaltic concrete pavement with a lot of filler in it is very stable, but not durable. The pavement gets hard and brittle, and may crack and ravel. Experience has shown that trouble can occur when the weight of filler in an asphaltic concrete mixture is more than about 1.2 times the weight of asphalt. This means that in a mixture that contains 6 percent asphalt, no more than about 7.2 percent of the aggregate should pass the No. 200 sieve. A requirement for a satisfactory and durable asphaltic concrete paving mixture is:

<u>THE AMOUNT OF AGGREGATE WHICH PASSES THE NO. 200 SIEVE SHOULD BE HELD AS CONSTANT AS POSSIBLE AND SHOULD NOT BE MORE THAN 1.2 TIMES THE AMOUNT OF ASPHALT IN THE MIX.</u>

<u>Asphalt Cement</u>

4. The asphalt used in asphaltic concrete mixtures is in a form called asphalt cement. It is made from crude petroleum oil*. First, the petroleum is heated to a high temperature to drive off the butane gas, gasoline, and kerosene. Further heating, in the presence of steam, produces paving asphalts of different consistencies*. The consistency of an asphalt cement is indicated by its penetration. Penetration is measured by the vertical distance a loaded blunt pointed needle enters the asphalt in a certain time at a certain temperature. The softer the asphalt, the higher the penetration. Asphalt

cement used for asphaltic concrete usually has a penetration, between 85 and 100 (85-100 penetration grade); harder grades, such as 55-70 or 70-85 are sometimes used.

The grades with lower penetration make more stable* mixtures, which are less likely to be pushed out of place by traffic. They are used for sheet asphalt and other types of pavements where additional stability is necessary. A sheet asphalt paving mixture is made with asphalt, fine sand, and filler. Such a mixture, in which less than about 30 percent consists of aggregate particles, 1/8 inch in size or larger, usually must be made with a low penetration asphalt cement because it lacks the stability furnished by the interlocking* of larger aggregate particles.

The asphalt cement supplied to a mixing plant should be checked frequently to make sure that it is of the penetration grade used in the design of the mixture and specified for the particular project. A daily penetration test is necessary when a mix for JA-1 sheet asphalt is being made. When a test sample is obtained at a batch plant, it should be taken at the point where the asphalt enters the weighing device, or from the circulating line that carries the asphalt from and back to the asphalt storage tank. The right grade of asphalt cement may have been shipped from the refinery, but the consistency may have been changed because it has become "contaminated"; that is, some other material has become accidentally mixed with it. Occasionally, some cut-back or other material remains in the tanker when the asphalt cement is loaded. The naphtha* or kerosene in the cut-back will then affect the consistency of the whole tanker load of asphalt cement. Another possible source of contamination at some plants is leakage from the circulating oil line used for heating the storage tanks. At a plant where two grades of asphalt are being used, separate storage tanks and separate circulating supply lines to the weighing device are required to prevent one grade from contaminating the other.

Asphalt which has been stored a long time changes in consistency and must be tested before use. A 1-quart sample must be taken as long before use as possible, as directed by the Materials Engineer, and sent to the Laboratory.

Trinidad Lake asphalt must be agitated continuously when in the storage tanks. About 20 percent of this material is very fine dust which will settle to the bottom of the tank unless the contents of the tank are kept moving. Loss of this dust will increase the penetration. If the agitation is stopped for any length of time, or seems to be defective, a check sample of the asphalt cement should be taken and tested.

Coarse Aggregate

5. Coarse aggregate for bituminous concrete is usually crushed stone, crushed gravel, or slag from a blast furnace. Crushed particles with sharp edges and corners interlock better than do round particles, such as those of uncrushed gravel, and give the pavement more stability. This type of stability* is desirable, since the pavement is not made more brittle, as it is when the filler content of the mix is too great. To get the right gradation, two sizes of coarse aggregate from the same source may be combined at the cold

feed, where the different aggregates are proportioned and combined before being put through the drier. However, all the aggregate in any one portion of the length of a binder course or wearing course (pavement layer) must be from the same source. Slag is more porous* than crushed stone or gravel, and additional asphalt is required to make up for that which soaks into the slag.

Coarse aggregate is tested for quality before it is delivered to the plant. However, it may become coated with dirt or contaminated with fine material which washes down to the bottom of a stockpile. Dirty aggregate should not be used, as the coating may prevent the asphalt from binding firmly to the surfaces of the particles. Upon arrival at the plant the coarse aggregate must be examined and tested for general compliance with Specification requirements relating to uniformity of gradation, cleanliness, and freedom from too many flat and elongated* pieces.

Fine Aggregate

6. Fine aggregate for bituminous concrete is usually considered to be the material that passes the No. 8 sieve. It may be either natural sand or sand manufactured by crushing stone, gravel or slag. Manufactured sand makes a mix of very high stability, but it may be hard to compact such a mix by rolling. A mixture of about equal amounts of natural sand and manufactured sand is sometimes preferred for this reason, and a mixture of this kind is allowed by the Specifications.

Manufactured sand made by crushing limestone of some types may produce a slippery pavement surface when used in an asphaltic concrete mixture in which the coarse aggregate is limestone from the same source. Under the action of traffic, some limestone takes a very smooth polish, like marble. If all of the aggregate is a type of limestone that will polish, traffic will produce a finish, somewhat like a polished marble floor, which will be very slippery when wet. Natural sand is usually harder than limestone. When the coarse aggregate is limestone and the fine aggregate is natural sand, the sand does not wear down and become polished; and parts of the sand grains that project from the coarse aggregate prevent the pavement from becoming slippery. Sand manufactured from Van Port limestone cannot be used in the wearing course when the coarse aggregate comes from the same source. However, such sand may be used in a binder course where there is no danger of polishing. Except for this restriction, two or more fine aggregates that meet Specification requirements, regardless of source, may be blended at the cold feed to get the required gradation.

Fine aggregate is tested for quality before it is delivered to the plant. However, it may be contaminated by clay or dirt, or may contain too much fine material because of segregation or washing down of fines to the bottom of the stockpile.

Any sand that contains clay lumps or roots or has a coating of dirt on the particles must not be used. Fine aggregate must be tested for gradation when it arrives at the plant. A sample must be sent to the Laboratory for check testing before work starts and once a month thereafter.

Mineral Filler

7. The filler includes the part of the aggregate that passes the No. 200 sieve as well as any commercial filler that is added. The commercial filler

may be portland cement, flyash, or dust made by grinding stone. Different types of filler have different effects. Commercial limestone filler is good for filling voids. Very fine materials, such as clay or silt, may make a mix more stable. However, a mix that contains too much fine material will be "tough" and cannot be rolled easily. Also, the finished pavement will be hard and brittle. The amount of asphalt required in a mixture changes with the quantity and type of filler. Once a mix has been correctly designed, the amount of filler should be kept constant and the type should not be changed.

Commercial filler must be kept dry in storage. If it absorbs moisture, the damp material may cause the hot mix to "foam" or to level off in the truck as if too much asphalt has been used. An asphalt mix is said to foam when steam from the aggregate blows small bubbles out of the asphalt, forming a foam something like that on sudsy water. Normally an asphaltic concrete mixture forms piles in the truck when dumped from the mixer. Too much asphalt or too much moisture in the mixture makes it so liquid that the piles flatten and the mix levels off in the truck.

Because the amount of filler has such a great effect on the voids and stability of an asphaltic concrete mix, any added commercial filler should be weighed into the batch very accurately. The part of the filler from the aggregates which is returned from the plant's dust-collection system during drying should be fed back to the hot elevator uniformly so that there will be a constant percentage of filler in the fine-aggregate bin.

Hydrated lime is a special type of filler used in small amounts in cold-mixed asphaltic concrete to improve the adhesion* of the asphalt to the aggregate. It also adds toughness and stability to the mix.

Plant Production of Asphaltic Concrete

8. In the production of asphaltic concrete, it is extremely important that the plant-mixed material meet all requirements of the Specifications. Specifications are the recipe for getting a good job. They are the result of years of experience and research in building pavements with the aggregates which are available in a particular area, so as to meet the demands of traffic and climate in that area.

Unless a pavement meets all Specification requirements, experience has shown that maintenance costs will be high. The Inspector is responsible for making sure that an asphaltic concrete mix meets the Specification requirements. His duties are of the greatest importance, since the best possible construction at the lowest cost to the State cannot be obtained unless the mixture produced at the plant is of uniformly good quality.

Getting the best possible asphaltic mixture requires careful inspection and control of the component materials and of the mixing process, in accordance with the Specifications and instructions. Several testing methods can be used by the Inspector to make sure that the component* materials and the completed mixture meet the requirements of the Specifications. However, since only very small samples of each day's production can be tested, there is much more to the Inspector's job than just making the required tests. He must be

familiar with the workings of the various parts of the asphalt plant, particularly the parts that control the composition and quality of the resulting paving mixtures. He is responsible for controlling the operations so that the end product is of uniform quality. Only under these conditions can samples of the aggregate or the completed mix be considered truly representative of the material produced.

If there is one key word to describe the quality production of asphaltic mixtures, it is UNIFORMITY. The aggregate in each stockpile must be of UNIFORM quality and gradation; the materials must be fed into the plant in a UNIFORM, controlled manner; the heating and drying of the aggregates must be UNIFORM; the separation of the aggregates in the several bins must be UNIFORMLY controlled; and the aggregates and the asphalt cement must be combined and mixed in a UNIFORM, consistent manner.

In order to get uniform quality, the entire mixing process must be performed in such a way that each part of the process is in balance with all other parts. The amount of the mixture dumped into the trucks cannot be more than that which can be thoroughly dried by the drier* and cleanly separated by the screens*. The capacity of the plant is limited to the capacity of the least productive unit in the production cycle, whether it be the drier, the screens, the pugmill*, or any other unit. For these reasons, the Inspector must be thoroughly familiar with all phases of the mixing process.

Stockpiles

9. Proper plant control starts with control of the aggregate stockpiles. To the extent required by the Specifications, each stockpile should be formed on a hard, tight base graded to drain rain water away rapidly. There should be enough distance between stockpiles to keep material from one pile from getting mixed with material from another. If two piles are close together, they should be separated by a tight bulkhead* which is high enough to prevent intermixing. Each pile should be built up in layers, and a layer should not be more than 4 feet thick. If a pile is formed in the shape of a cone by dumping all of the aggregate at the top in the center, the material is sure to be segregated. The coarse aggregate then rolls to the outside, and a core of finer material is left in the center. It is almost impossible to get a representative sample from a coned stockpile; it is equally difficult to get well-graded material from the pile to feed the plant.

The aim of stockpile control is uniformity. If a portion of material is taken from the center of a pile of coarse aggregate that was formed in the shape of a cone, that portion will contain more fine particles than will other portions with the same volume. When this unusually large amount of fine material goes through the plant, it will overload* the screens having smaller openings. As a result, some of the finer aggregate will "overrun"* into bins that should contain coarser aggregate only, and the mix will not be uniform.

Cold Feed

10. The cold feed, where the aggregates are first proportioned and blended, is the heart of the plant. The gradation of the fine aggregate is set at the cold feed. Nothing can be done to change it beyond that point. The gradation

of the combined aggregates is also set at the cold feed. If the different sizes of aggregates are not fed in the right proportions, one of the plant bins will run over, and there will be a waste of dried aggregate. The operator weighing the aggregates for a batch may be tempted to "Pull Heavy", or deliberately use too much material from the overflowing bin, with the result that the mix will be thrown out of balance (and not meet Specification requirements).

Finally, the capacity of the plant and the uniformity of its operation are fixed at the cold feed. If the rate of feeding aggregate to the drier is slower than the rate at which the aggregates are being weighed out, the bins will run empty. If the combined aggregates are fed to the drier too rapidly, the bins will run over. In the first case, the plant will have to stop; in the second, the drier will have to stop. These unnecessary stops have a bad effect on uniformity of the mix.

There are many ways to proportion the aggregates at the cold feed. They range from a belt conveyor with a simple adjustable gate to vibrating or oscillating pans. The rate at which material is fed to the drier depends to some extent on the amount of material in the cold bins. All cold bins should be kept nearly filled, no bin being allowed to run low.

The cold-feed system sometimes has two sets of controls. One set controls the proportions of the different sizes of aggregates fed to the plant. The other controls the total amount of combined aggregate. Such a system allows for some flexibility in rate of production without frequent changing of the individual feeds.

Once the cold-feed controls have been set correctly, the Inspector should check them frequently to make sure that no opening has become plugged and that all aggregates are being fed uniformly at the correct rates. If there is anything wrong, it must be fixed right away, even if the plant must be stopped. The aggregates in the mixture produced by the plant will not have the right gradation if there is anything wrong with the cold feed.

Drying Aggregate

11. The plant drier has to do two jobs. It drives off the moisture in the aggregate and heats the aggregate to the required temperature. Within the limits of its capacity and efficiency, how well any drier does these jobs depends mostly on the amount of oil burned, on the amount of surface moisture on the aggregate particles, on the amount of moisture which has soaked into the aggregate, and on the rate at which material is fed to the drier.

There is a limit to the amount of oil that can be burned efficiently in any drier. If an attempt is made to increase the capacity of the drier by burning an amount of oil above this limit, some of the oil will not be burned. The unburned oil will then show up as black smoke and soot coming out of the stack. It is not considered good practice to operate with a "black stack", as a coating of unburned oil may be left on the aggregate and this oil may

affect the stability or durability of the asphaltic concrete. A black stack usually means that the rate at which aggregate is being fed to the drier by the cold feed should be reduced. To avoid a black stack, the rate of the cold feed should be reduced when the aggregates have a high moisture content, as after a heavy rain on the stockpiles.

Aggregates which are porous* and soak up a lot of water cannot be dried easily. Even when the aggregate is heated to a high temperature, considerable time is needed for the small amount of water soaked up by the particles of coarse aggregate to come to the surface and evaporate. If there is not time enough for this moisture to evaporate before the aggregate is placed in a plant bin, the moisture will continue to come out and the aggregate will "sweat"* in the bin. The moisture may even continue to come out after the aggregate is mixed with asphalt. If it does, the result will be foaming and stripping of the mix in the truck and under the roller at the job. A mix containing too much moisture cannot be accepted. Any mix which shows stripping of the asphalt from the aggregate during handling, placing, or finishing should be rejected.

To check for incomplete drying, take a shovelful of the heated aggregate from the drier discharge chute. Immediately pass a cool mirror (face down) just above the aggregate with a slow, deliberate motion. Turn the mirror over and look for any fogging on the face that shows moisture is still coming from the aggregate.

It is not up to the Inspector to tell the Contractor how to reduce the moisture content. The Inspector must know, however, that heating the aggregate to too high a mixing temperature is not the answer; the Inspector should be on guard to see that this is not done. The aggregates should be heated to a temperature that will produce a completed mix with a temperature between 265 and 325 degrees F., and will be within 15 degrees F. of the mixing temperature set by the District Materials Engineer. (Except for FB-1. See Specifications).

Pyrometer

12. The plant must have a thermometer or electric pyrometer* at the discharge chute of the drier to show the temperature of the heated aggregate. This device shows the average temperature of the several sizes of aggregate at this point. The temperature of the material in each bin should be measured by a series of tests when the plant is running steadily and the pyrometer shows a uniform temperature. At the same time the temperature of the completed mix should be recorded. In this way, the general relationship between the pyrometer reading and the mixing temperature can be found. A difference in temperature between the fine and coarse aggregates in the bins is a warning of incomplete drying. This is so because the continued evaporation of water coming out of the coarse aggregate has a cooling effect and the temperature of coarse aggregate will be lower than that of the fine aggregate. It is not good practice to have the temperature of the fine aggregate in the bin more than 40 degrees F. above the mixing temperature. A high aggregate temperature causes absorption of the asphalt by the aggregate and increased hardening (reduction of penetration) of the asphalt.

Dust Collectors

13. Dust collectors must be installed in most plants. As far as the mix is concerned, the most important requirement for this part of the plant is that it return the collected dust uniformly to the plant. If the mix contains too much material that passes a No. 200 sieve (shown by extraction tests) part or all of the collected dust should be wasted.

Screening of Heated Aggregates

14. After passing through the drier, the heated aggregates and the collected dust are lifted by the hot elevator to the top of the plant. There they are separated into various sizes by the plant screens. Each size goes to a separate bin. The upper and lower limits of size of the aggregate in each bin are set by the Specifications. There is also a requirement that at least 85 percent of the material in each bin fall within these size limits.

The gradation of the aggregate in the No. 1, or fine, bin is controlled mainly by the cold feed and by the amount of fines returned from the dust collector. If the plant is operated properly, gradation of the material in the other bins is controlled by the plant screens and should stay practically constant. If too much material is fed to the screens, the layer of aggregate on the screens will be so thick that some of the fine material which should go to the No. 1 bin will "carry-over"* to the other bins. The rate at which the screens will separate the aggregates cleanly depends on many factors. However, more than 15 percent of fine material in a bin for coarse aggregate is a definite sign of trouble. It is up to the Producer to locate the cause of the trouble and correct it. A uniform mix cannot be produced when there is a large amount of carry-over, and the plant must not be allowed to continue to operate when this happens.

Bin Overflow Pipes

15. Each bin must have an overflow pipe to keep the material in the bin from backing up and overflowing into other bins. The overflow pipes should be checked to make sure that they are not clogged and are working properly. If the cold feed is not set properly, one bin will fill up and overflow. If the overflow gets into another bin, a large amount of mix which does not meet the Specifications may be produced before the trouble is noticed.

Gates on Hot Bins

16. The gate that allows material to flow from each bin to the weigh hopper must close tightly and not leak. The gate on the fine-aggregate bin should be checked often to make sure the fine material does not keep on flowing into the weigh hopper after shut-off.

Addition of filler also should be checked closely. Changes in the amount of filler have more effect on the mix than do changes in the proportions of the other aggregates. If flyash is used for filler, it is very important to check the tightness of the gate or other device which controls the amount added to the batch in the weigh hopper. This material flows like water, and it is very hard to control the flow.

Bitumen-Control Unit

17. Since the binder* content has a very important effect on the stability and durability of asphaltic concrete, the right amount of asphalt (or tar) must be accurately measured into <u>every</u> batch. When a meter is used, it must have a bypass so that the asphalt can be drawn into a drum and its weight compared with the quantity shown on the meter. There should be continuous circulation of the asphalt from the storage tank to the metering device and back to the storage tank. There must be a thermometer in the circulating line to show the temperature of the asphalt in the line at all times. The temperature of the asphalt must stay about the same and should be between 265 and 325 degrees F. (Except for FB-1. See Specifications).

Asphalt is sometimes delivered to the plant at a very high temperature. If this very hot material is pumped into a nearly empty storage tank, the asphalt pumped from the tank to the plant may be so hot that it affects the accuracy of metering and raises the mixing temperature. The temperature of the asphalt in the circulating line should be checked during and immediately after a delivery.

When the quantity of asphalt added to each batch is controlled by weight, the scales must be checked frequently with test weights. The scale beams and knife edges must be inspected to make sure that they stay clean and that the scale will show small changes in weight under actual operating conditions.

During batching the scale should be watched to make sure that the right amount of asphalt is shown by the scale and also that the scale returns to zero when the asphalt is dumped into the mixer. If the scale does not return to zero, it means that asphalt has accumulated in the weigh bucket, or that it has become coated with a heavy layer of dust. If this happens, the mix will have less than the specified asphalt content.

Metering devices on automatic and continuous plants must be checked very carefully. They sometimes make consistent errors in proportioning, and it is very difficult to discover these errors, except by extraction tests on the completed mix.

Asphalt should be sprayed in several small streams or a thin uniform sheet extending over the full length of the mixer. The spraying equipment should be checked often, since any stoppage in the spray bars may mean that a longer mixing time is needed to completely coat the aggregate with asphalt.

A dry batch (one at which not enough asphalt has been added) sometimes is dropped into a truck. This happens at both manually* operated and automatic* batch plants. The Inspector must be watching for a dry batch and must reject the batch before another batch can be dropped on top of it.

Weighing Aggregates

18. The gate at the bottom of the weigh hopper must close tightly. If it does not, fine material will leak into the mixer and throw the mix out of balance. To help prevent this leakage, it is good practice to weigh the coarse aggregate before the fine aggregate.

The scale on the weigh hopper should be checked when the plant bins are full, since loads on the plant framework sometimes cause the scale beams and balance points to bind. The results may be that the weights shown, when the plant is operating, are not correct.

Mixing Bituminous Concrete

19. Mixing of the aggregates, filler, and asphalt is intended to produce a mixture so uniform that each unit volume (such as a cubic foot) will contain the same amount of each size of aggregate and all particles of aggregate will be uniformly coated with asphalt. To do this, the paddles on the ends of the arms, attached to each of the two shafts in the pugmill, should be set so that, as the mixture is being tumbled and stirred, the material will be moved "around the box". This arrangement prevents "dead spots" at the ends and corners of the pugmill where the material would not be mixed uniformly. After the asphalt has been added, it should be mixed with the aggregate for at least 40 seconds. Whether or not the mixing time is long enough can be judged by screening the coarse aggregate out of a sample of the hot mix. After the particles have cooled, they can be examined for coating under a good light. When the coarse aggregate particles are examined closely under a strong light, small uncoated areas or "specks" may be seen on some of the particles. Good practice requires that not more than 5 percent of the coarse particles show these "specks" after mixing is completed.

Mixing Temperature

20. Each grade of asphalt from each source has an ideal mixing temperature. This is the lowest temperature at which the asphalt becomes fluid enough to flow over the surface of the aggregate and form a continuous coating. If the mixing temperature is too high, the asphalt will be so thin that some of it will soak into the aggregate and the mix will be dry and brittle, or some may drain off the aggregate while the mix is being hauled to the job. More important, the asphalt hardens during mixing if the temperature is too high; this hardening shortens the life of the pavement. An asphalt which had a penetration of 90 when added to overheated aggregate may have a penetration of only 50 a minute later, after it has been mixed with the aggregate. Rapid hardening occurs because the asphalt is present as very thin films on the surfaces of the aggregate particles during mixing, and the oxygen in the air quickly combines with the asphalt and hardens it. The higher the mixing temperature, the harder the asphalt becomes during the mixing process. After the mix is rolled to form the pavement, the asphalt continues to harden, but very slowly. When the penetration drops to about 30, the pavement becomes so brittle that it cracks. The more the asphalt has hardened during mixing, the shorter the time needed for the pavement to reach this cracked condition. For this reason, the mixing temperature has a lot to do with the durability of the pavement.

The best mixing temperature for any asphalt is the temperature at which it has a viscosity of 75 to 150 seconds. Viscosity is measured by the length of time it takes for a certain amount of the material to run through a hole of a certain size at a certain temperature. When asphalt is heated it becomes thinner (more fluid) and takes less time to run through the hole. The thinner it is, the lower the viscosity. The refiner who supplies the asphalt

will furnish charts which show the viscosity of the asphalt at various temperatures. From these charts the District Materials Engineer determines the temperature range in which the asphalt has a viscosity of 75 to 150 seconds, and he sets the mixing temperature accordingly. It is important to the life of the road that every batch is mixed as nearly as possible at this temperature. Every batch should be within 15 degrees F. of this temperature when it is dropped into the truck.

Continuous Mix Plants

21. A continuous plant has the same parts as a batch plant up to the point where the heated aggregates are drawn from the bins. At this point the aggregates are continuously proportioned by volume instead of being put into a hopper and weighed. Proportioning of the different sizes is controlled by the amount of material flowing through an adjustable gate on each bin onto a moving conveyor belt. The rate of production of the plant is fixed by the total amount of material flowing through the gates. Each gate must be set to pass the right part of this total amount to give the specified gradation of the combined aggregate in the mix. If added filler is used, it is fed to the stream of hot aggregate before the aggregate enters the continuous mixer. At, or close to, the point where the aggregate enters the mixer, the asphalt is sprayed onto the aggregate from nozzles. The asphalt is usually pumped first from the large storage tank to a small supply tank on the mixer, and then from this tank to the spray nozzles.

The aggregates and the asphalt enter the mixer at one end, and the mixed material flows out of the other end. The length of time for which the material is mixed depends on the quantity of material in the mixer. This quantity is controlled partly by the height of an adjustable bulkhead at the discharge end of the mixer. Additional control is obtained by turning some of the mixer blades near the discharge end of the mixer so that they hinder the flow of material.

If the stream of mixed material is allowed to fall directly into a truck, it tends to segregate, so that the coarse aggregate goes to the far side and ends of the truck body. To prevent segregation the mixer usually discharges into a "gob-box", and the material is dumped into the truck from this box after it is full.

A continuous plant can produce a very uniform mixture if the material is supplied to the mixer uniformly. Overrun of material from one hot bin to another can spoil the balance of the mix. If the amount of material in either a bin of hot aggregate or the asphalt supply tank is allowed to become too small, the mix is thrown entirely out of balance. For this reason, the hot bins, and the supply tank, usually have "tell-tales" which warn the operator and the Inspector when the surface of the material drops below a certain level.

Loading Trucks

22. Trucks should be checked before being loaded with hot mix to make sure that the bodies are clean. There must be no material sticking to the sides or bottom of the truck body, and its inside must be free from any oil or solvent that might affect the mix. If the truck has been cleaned with a

solvent (like diesel fuel), all of it must be removed before the truck is loaded. If a pool of oil is left in the bottom of the truck body, it will dissolve some of the asphalt in the mix. When the load is dumped into the finisher, this oily material will get into the pavement and show up as a "fat" or flushed spot in the surface.

It is not good practice to load a truck in such a way that the mix segregates. Some mixers throw particles of coarse aggregate to one side of the truck when emptying the mix. If the mix is dropped too far when being dumped into the truck, the coarse particles tend to go to the sides and ends of the body. This segregation causes trouble at the job, particularly in making a good longitudinal joint. If there is segregation during loading, it should be called to the attention of the District Materials Engineer.

Responsibility and Duties of Plant Inspector

23. The responsibility and duties of the Plant Inspector and the directions given here apply particularly to the production of ID-2 mixtures and generally to the production of all bituminous mixtures. Exceptions and special requirements are given for some mixtures.

The Plant Inspector must be familiar with, and have available for reference, this Manual, the Department Specifications (Form 408), Specifications for Bituminous Materials (Bulletin 25), and the Standard Specifications for Bituminous Mixing Plant Requirements (ASTM Designation: D 995).

The Department Specifications note a few exceptions to ASTM 995. Otherwise, plants must comply with this ASTM Specifications.

The Plant Inspector must make sure, before production of any mixture begins, that the plant meets all requirements of the Specifications, is capable of satisfactorily producing the specified mixture, and has been approved by the Department.

After production starts, the Plant Inspector must make sure that the producer is operating and controlling the plant strictly in accordance with the Specifications, from the time the raw materials arrive until the completed mixture has been loaded for delivery. The fine aggregate, coarse aggregate, bitumen (asphalt or tar), and filler must meet Specification requirements. Also, the materials must be combined in such a way that the amount of aggregate and bitumen in a binder course or wearing course will be the same as shown by the job mix formula, within the limits of the Specifications which apply.

Control samples of bituminous material and mixtures must be taken as described below and sent promptly to the Laboratory. All samples must be identified completely and accurately.

Unapproved Material

24. The Producer may want to use in the mixture materials which have not been approved previously. Samples of each such material must be taken by the District Materials Engineer and sent to the Laboratory as early as possible before the start of paving. If there is not enough "lead time" there will be a delay until the necessary tests have been completed. Should the source of supply of any material change from that of the first sample, new samples must be sent in.

When asphalt that has been tested and approved at the refinery before shipment, has been in storage for a long time, or when there is a question about its quality, a 1-quart sample must be taken as directed by the Materials Engineer and sent to the Laboratory for testing some time before the material is used. It is always necessary to determine the suitability of an asphaltic material that has been in storage.

<u>Sampling Asphaltic Material</u>

25. When material is sampled from a tank car, truck, or storage tank, the procedure given in Chapter XI should be used. The identification tag on the sample must show its source.

The actual percentage of bitumen by weight in Trinidad asphalt cement, cut-back asphalt, or asphaltic emulsion must be gotten from the Laboratory, unless this quantity is shown on the acceptance card or affidavit for the material. The purpose of getting this percentage is to allow adjustment of the percentage of bituminous material to be used in the mixture, when necessary.

When a cut-back asphalt* or an asphaltic emulsion* is inspected at the refinery, the acceptance card or affidavit should show the bitumen content. A cut-back or emulsion of doubtful quality, or any asphaltic material that has been stored for 1 month or longer, must be resampled.

<u>Sampling Fluxes</u>

26. A 1-quart sample of naphtha, priming compound, workability compound, or asphaltic flux oil must be taken from each tank car or truck load. The sample should be taken with a weighted can or bottle that has an opening not more than 2 inches in diameter, and has a stopper with a string or wire attached to it. After the can or bottle has been lowered to the bottom of the tank, the stopper is removed by pulling on the string or wire. The can or bottle is then pulled out slowly and steadily so as to collect material from all levels.

<u>Sampling Fine Aggregate</u>

27. Fine aggregate must be sampled and tested when it arrives at the plant. The methods of sampling and testing are described in Chapter XI. Also, samples must be sent to the Laboratory for check testing before the start of the work, and once a month after start-up.

When permitted in the Specifications, two or more fine aggregates meeting the Specifications may be blended at the cold feed elevator to improve the gradation of the fine aggregate in the mix.

<u>Sampling Coarse Aggregate</u>

28. Coarse aggregate must be sampled and tested when it arrives at the plant. The methods of sampling and testing are described in Chapter XI. Also, samples must be sent to the Laboratory for check testing before the start of the work, and once a month after start-up.

Coarse aggregates type 1B and 2B from the same source may be blended, providing the blend is continuous during the days operation and the percentage of blend is constant.

Sampling Filler

29. One sample of filler must be taken from each of 8 to 10 bags from scattered locations in each railroad car or truck load. The individual samples must be put together, mixed, and successively divided into quarters until a sample weighing about 100 grams remains. The filler must be tested for gradation by using sieves of specified sizes. Samples of filler must be sent to the Laboratory for check testing before the start of the work, and once a month thereafter.

Sampling Hydrated Lime

30. A sample of hydrated lime must be taken from each shipment. It must be a combined sample taken from 8 to 10 bags in scattered locations in the railroad car or truck.

Duties of Plant Inspector During Production of Mixtures

31. The Plant Inspector must check all scales daily with test weights, as described in Chapter XI. The test should cover a range of scale weights up to the batch weights. He must also make or check necessary plant tests of materials; check the proportions of materials in the mixture, the mixing time, and the temperature of the materials and mixture; and make sure that the completed mixture meets all requirements of the Specifications. He must also keep a record of the output of the plant and of the delivery and use of materials at the plant, as necessary; and must make out and send in daily reports.

The Plant Inspector is responsible for checking the accuracy of the quantity of each material put into each batch. When material is being produced for use on Department jobs a Department Inspector must be present on the mixing platform at all times to watch the weighing of each material going into the mixtures. The Plant Inspector has to verify the correctness of the weights of materials in the batch and its quality by filling out and signing the Plant Inspection Notice, Form 4128.

Each truck load of mixture sent out from the plant must be accompanied by the white original of the Plant Inspection Notice, Form 4128, properly made out and signed by the Department Inspector assigned to the plant. This form shows the Inspector on the job that the mixture was produced according to Specifications under the supervision of an authorized Department representative.

When the material is shipped by rail, Form 4128 must be completed by the Plant Inspector and the white copy mailed to the District Engineer or District Maintenance Superintendent. This policy applies to both contract and maintenance work. All duplicate (yellow) copies of Form 4128 are attached to the Asphalt Plant Report, Form 448, and sent to the office of the receiving District. When a plant is shipping on a single day, material under more than one purchase order, to more than one contractor, or both to a contractor and under a purchase order, a separate book of forms should be used for each job.

The Inspector on the mixing platform must make sure that the aggregate hoppers and the asphalt bucket swing freely during the weighing process and that the asphalt bucket empties completely after each batch is dumped into the pugmill. He must also check the tare weight of the empty asphalt bucket frequently. If the scales do not return to zero when the bucket is dumped, an allowance must be made for the weight of dust that has settled on the bucket or for asphalt left in the bucket after each dump. If the quantity of asphalt is metered, the plant operator must furnish charts showing the volume-weight relationship for the asphalt. Before any of the materials are mixed, the Inspector must check the completeness of drying and the temperature of the aggregates, and the penetration and temperature of the asphalt. The aggregates and asphalt must be brought to the proper mixing temperatures. The completed mix must have the right temperature; a plus or minus tolerance of 15 degrees F. is permitted to allow for weather conditions and to provide workability on the job.

Choice of the exact temperature of the completed mixture is based on the time required to deliver the material to the paver, the weather conditions, and the temperature-viscosity relationship for the asphalt. Current viscosity charts, developed and provided by the refinery, must be available at the plant at all times. With this information, the District Materials Engineer will set the temperatures of the completed mixture at the plant and at the paver.

The Plant Inspector must measure the temperature of the first truck load of material before it leaves the plant, and the temperature of every fifth load thereafter. He must record these temperatures on the Plant Inspection Notice, Form 4128. A load having a temperature more than 15 degrees F. higher or lower than that specified may be rejected at the plant.

The Plant Inspector must make sure that the mixer is kept in good working condition. Worn liners, broken or worn paddles and leaking gates should be repaired promptly. He should be sure that the timer and the asphalt line thermometers are working properly. If the timer should get out of order, the producer may control the mixing time for the rest of the day by using an accurate clock with a large second hand. If an asphalt line thermometer breaks, the producer may operate the plant for the remainder of the day by using an accurate hand thermometer frequently to measure the temperature of the asphalt directly before it is fed into the mixer. One way to do this is to draw the heated asphalt from the circulating line into a container holding about one quart. Stir this material with the thermometer and read the temperature.

The bin gates and the weigh-hopper gate must be built so that the aggregates are distributed uniformly over the full length of the pugmill when the batch is dumped into it. Spray bars and asphalt buckets must be built and placed so that the asphalt is added to the batch quickly and over the full length of the mixer, to make sure that each particle of aggregate is coated rapidly and adequately.

The mixture must be hauled to the work in trucks with tight bodies, which are free from dust, screenings, petroleum oil, or solvents that might affect the asphalt. Each truck body must have a cover large enough to protect the whole load. When necessary, the bottom and sides of the truck body must be insulated to prevent loss of heat, so the mixture will be delivered hot enough for laying. Unless otherwise authorized or directed, trucks are to be sent out from the plant on such a schedule that all material may be placed and rolled during daylight hours.

Samples for Extraction Test

32. Unless otherwise directed, the completed mixture must be sampled once daily for an extraction test. A sample for the daily extraction test must be taken early enough to permit results of the test to be ready 3 hours after the plant starts operation. Samples for daily extraction tests must be taken by trained plant employees under close observation of the Plant Inspector. Samples for tests made at the Department Laboratory are to be taken by the Plant Inspector.

Unless otherwise directed, two samples of binder-course material and two samples of wearing-course material are to be sent each week to the Laboratory for testing. Bituminous concrete for patching, furnished to the Maintenance Department under purchase orders, is to be sampled from time to time as directed by the District Materials Engineer. The rate of sampling should be one sample for every 1000 tons produced at a plant.

The Asphalt Plant Report, Form 448, shows results of extraction tests, grading analyses, and similar information. This report must be sent in every day a plant is in operation, regardless of the amount of bituminous concrete produced.

Mixed material is to be sampled in this way: A number of small portions should be taken from each of the individual batches that make up a truck load. These portions should be taken from several locations in the batch. All the small portions that represent the entire truck load are placed on a metal plate and mixed thoroughly. The metal plate should be warmed, or coated with a light covering of limewater, to prevent the asphalt and fines from sticking to the plate during mixing. The scoop used to take the sample should also be warmed to keep the fines and asphalt from sticking to it. The sides of the scoop must be high enough to permit the small portions to be lifted from the batch and put on the metal plate with no loss of material. Care must be used to avoid over-heating the plate or scoop; it should only be warm enough to prevent sticking of the fines or asphalt. The scoop or plate must never be hotter than the material in the batch. After the material on the plate has been mixed so that there is no segregation, a sample for the extraction test and a sample for the Laboratory tests are taken by collecting small portions from different parts of the mixture on the plate.

Another way is to use an open metal container, 2 feet square and 5 inches high, with handles, to get samples of the plant mixture. Just before the last batch is dumped into the truck, the pile of material already in the truck is flattened slightly. The container, with ropes attached to its handles, is then placed on top of the pile, directly under the center of the pugmill discharge. The last batch will then drop on top of the container. After the truck has moved away from under the pugmill, the container filled with the mixture can be lifted out of the pile by means of the ropes.

At least two additional samples of the mixture, properly identified, must be taken and kept at the plant by the Inspector until tests have been made at the Central Office Laboratory and the mixture has been approved. These samples are saved for check tests by the Laboratory or at the plant in case there is any question about the quality of the mixture. The District Materials Engineer decides when samples for check tests are to be used.

If sampling methods just described cannot be used, the District Materials Engineer will set up a sampling procedure for the particular plant.

Daily extraction tests at the plant are made by a trained plant employee under the close observation of the Plant Inspector. Extraction tests are to be made by methods given in the Department Manual, "Field Extraction Tests for Bituminous Mixtures." When equipment different from that described in this Field Manual is approved for use, instructions will be issued for making the test with such equipment. All test results must be turned over to the Department and shown on the Asphalt Plant Report, Form 448.

Sampling Mixtures for Bituminous Surfaces

33. A mixture for an ID-2 surface, a FJ-1 surface, or the binder course* of a JA-1 surface must be sampled as described before. A sample weighing about 10 pounds is to be sent to the Laboratory in one of the cardboard cartons furnished for this purpose.

Samples of a mixture for the sheet-asphalt* wearing course of a JA-1 surface must be taken in the manner described before. Samples for a new surface are to be sent to the Laboratory daily or as directed; samples for maintenance patching are to be sent in for each 500 tons or for each purchase order of less than 500 tons delivered from a plant. Each sample is to be sent to the Laboratory in a carton furnished for this purpose. When filled, the carton contains a sample that weighs about 7 or 8 pounds.

A mixture for FB-1 surface or A or B patching material must be sampled as described before, but the tools and metal plate for sampling and mixing the material are not to be heated. The material, after being mixed on the plate, must be cured before it is placed in the sample container or before the extraction test is made. The sample is cured by allowing it to stay on the plate until all of the naphtha* has evaporated. It must be protected during curing, so that no water, dust, or other foreign material can get into it. A sample weighing about 10 pounds is to be sent to the Laboratory in the 1-gallon, friction-top can furnished for this purpose.

Bituminous premixed stockpiled patching material should be sampled at a plant after the producer has built up a stockpile. Only one sample of the mixture is required. When the producer believes that the material has cured long enough, he asks the District Materials Engineer to supervise the collection of a sample and to send it to the Laboratory for check testing. No deliveries are to be made to the Department from this stockpiled material until it has been approved by the Laboratory. New material must not be added to any stockpile after it has been sampled. If additional material is produced, separate stockpiles must be formed and sampled.

When stockpiled material is shipped by rail, each car must be sampled at the point of delivery. Samples weighing about 10 pounds are to be sent to the Laboratory in the 1-gallon cans furnished for this purpose.

Form 447, Sample Identification must be enclosed with each sample of bituminous concrete sent to the Laboratory. The form is filled in by the Plant Inspector. A copy of this form must be sent to the District Office.

Daily Reports

34. Two copies of the daily Asphalt Plant Report, Form 448, must be mailed to the District Office. The forms are numbered consecutively (in order). If desired information about the work is not shown on the front of Form 448, it must be shown on the back. When work at the plant stops for several days, the Plant Inspector does not have to send in reports for those days. However, the first report after work has started again should show how long the plant was idle and the reason for stopping the work. The Plant Inspector must keep copies of all reports and records. He should also keep a daily diary of important events and facts relating to the work. The diary should contain reasons for acceptance or rejection of materials, instructions or suggestions to the Contractor, and instructions from the District Engineer or the District Materials Engineer. A straight-line chart must be kept up to date by the Plant Inspector and posted at the plant at all times. It shows daily aggregate gradations and asphalt content of the mixture, and is helpful in any study of the uniformity of plant operations.

Plant Control of Mixture for JA-1 Surface

35. The control procedures at a plant producing a mixture of a JA-1 surface are the same as those described for an ID-2 surface, with the following exceptions.

Fine aggregate in a mixture for the sheet-asphalt wearing course of a JA-1 surface is to be heated to a temperature of at least 300 degrees F., but not more than 400 degrees F. The filler must be added to, and mixed thoroughly with, the hot fine aggregate. Each batch must be mixed for at least 1 minute, but mixing must be continued, if necessary, until a uniform mixture is obtained. All particles of aggregate in the mixture must be coated uniformly.

In addition to the equipment needed for other mixes, the producer must supply a penetrometer and a constant-temperature bath which has an accurate thermometer.

The Inspector must make daily penetration tests of the asphalt cement used in the day's work.

The Special Provisions of a contract will usually set a working range of 10 points in penetration for the asphalt cement used in mixture for a JA-1 surface. If tests results fall outside this range, the District Materials Engineer should be informed.

The mixture for a JA-1 surface must be sampled and tested as described for an ID-2 mixture. When a sample of the mixture is sent to the Laboratory, the Inspector must send a sample of the asphalt cement with it. Asphalt samples are sent in containers (3-ounce ointment boxes) furnished for this purpose. A penetration test should be made on the asphalt sample at the plant before it is sent to the Laboratory.

Plant Control of Mixture for FJ-1 Surface

36. Control procedures for the materials in a FJ-1 mixture are the same as those for asphalt and fine aggregate for an ID-2 mixture. All plants produc-

ducing FJ-1 mixtures must be approved by the District Materials Engineer the same as plants producing other mixtures. A representative of the District Materials Engineer goes with the District Materials Engineer when this inspection is made.

When asphalt cements of Classes A-1 and BM-1 are being used at the same plant, separate storage tanks and circulating lines are required for each material.

The bituminous material must meet the requirements of Bulletin 25. It may be heated to the temperature required to get a workable mix. The temperature must be uniform throughout the material and must not be above the limit specified or as set by the District Materials Engineer.

Materials for Patching Mixtures

37. There are two types of plant mixtures for patching: Type A for deep patching; and Type B for skin patching. Plants making these patching materials must be approved by the District Maintenance Engineer and District Materials Engineer.

The bituminous material for a patching mixture may be asphalt cement of Class BM01; asphaltic cement cut-back of Class C-1, Class NC-1, or Class CE-3; coal tar cut-back or Class P-2; or water gas tar cut-back of Class P-3. MC-2 or MC-3 is required for Bituminous Premixed stockpiled patching material. Each material must meet the requirements in Bulletin 25. When asphaltic cut-back or tar cut-back is used, it may be heated at the plant to get a uniform temperature of the material. The temperature must not go above 175 degrees F. for an asphaltic cut-back and emulsified asphalt, and not above 120 degrees F. for a tar cut-back.

Petroleum naphtha* may be used only with asphalt cement of Class BM-1. The volume used must be measured accurately by an approved gaging or metering device. Naphtha is to be sampled and shipped as described before.

Fine aggregate and coarse aggregate for a patching mixture must be sampled and tested as described for materials for ID-2 mixtures. Gravel for a patching mixture must have at least 85 percent of crushed particles, and at least one face of each particle must have resulted from fracture. Nicked gravel particles cannot be considered as crushed particles.

Type 2B coarse aggregate is to be used for a Type A patching mixture, and Type 1B coarse aggregate for a Type B patching mixture. Fine and coarse aggregates meeting Specification requirements are to be combined so that the total aggregate in a patching mixture of either type will meet the gradation requirements in Bulletin 27 for that type.

Producing and Sampling Patching Mixture

38. All aggregates and bituminous materials in a patching mixture must be proportioned by weight, as for an ID-2 mixture. Mixing of the aggregate and bituminous material must be continued until they are thoroughly and uniformly mixed. In no case should the mixing time, measured from the time the bituminous material is added, be less than 1-1/2 minutes; when asphalt cement and naphtha are used, it must not be less than 2-1/2 minutes.

The aggregates must be clean and dry. When they must be heated, their temperature at the time of mixing must not be more than 110 degrees F.

When asphalt cement and naphtha are used with stone or gravel as the coarse aggregate, the materials must (unless otherwise directed) be put in the mixer in this order: coarse aggregate, naphtha, asphalt cement, and fine aggregate. When slag is used as the coarse aggregate, the materials are to be added in this order: slag, asphalt cement, naphtha, and fine aggregate. No new material should be added until the materials already in the mixer have had time to become mixed thoroughly. Naphtha must be sprayed over stone before the asphalt cement is added. Slag must be coated with asphalt cement before the naphtha is sprayed on. The asphalt cement and the fine aggregate are to be added in such a way that they are distributed evenly throughout the mix; they should not be dumped in one place.

When asphaltic cut-back or tar cut-back is used, the materials are to be put in the mixer in this order: coarse aggregate, bituminous material, and fine aggregate.

The Inspector should see to it that samples of a patching mixture are taken, and that extraction tests are made, as often as the District Engineer directs. The results of all tests must be shown on the Asphalt Plant Report, Form 448, and both copies sent daily to both the District Office and the Laboratory.

Form 4128 must be filled out properly for each truckload of material. The white copy goes to the foreman placing the material. The yellow copy is attached to the Asphalt Plant Report, Form 448, and sent to the District Office.

The uniformity band* on the gradation chart does not apply to patching mixture of Type A or Type B and Bituminous Premixed stockpiled patching material.

<u>Job-Mix Formula for Control of Mixture</u>

39. The Specifications give general composition limits for various paving mixtures. These limits must control the make-up of mixtures made from many different materials that meet Specification requirements. The Specifications set maximum and minimum values in all cases. To provide closer control for a particular project, it is necessary to set narrower ranges of limiting values. This is done by the job-mix formula.

No work can begin until the Producer sends in a mix design and it is approved. In the case of a mixture for an ID-2 surface, the District Engineer sets the quantity of asphalt cement and the quantity of aggregate that passes a No. 8 sieve. Each of these quantities is given as a percentage by weight. Using these percentages, the Producer then works out a trial mix design and sends it to the District Engineer. The trial mix design must be approved before production of the mixture begins. After two days of trial run of the plant to find out if any adjustments must be made in the mix design, the Producer submits a final design for approval by the District Engineer. The percentages of materials in the mixture supplied by the Producer must be within the limits given in the Specifications and set by the job-mix-formula.

The daily extraction tests made at the plant and the daily gradation tests on the combined aggregates taken from the hot bins show the asphalt content and the aggregate gradation of the mixture actually being supplied. Any

differences from the percentages fixed by the final approved job-mix formula must not be greater than those allowed. If the gradation of the combined aggregates does not fall within the uniformity band on the gradation chart, the plant superintendent must be notified at once, and the corrections must be made as soon as possible. The plant may continue to operate for a reasonable length of time while the operator finds and corrects the condition causing the variation from the uniformity band. This is allowed, provided that the actual percentages are between the Specification limits and prompt action is taken. However, if the actual percentages are outside the Specification limits, or corrections are not made within one day, shipments to any Department project must be held up. Shipments can begin again when the producer shows that he can furnish a mixture which meets the requirements of the job-mix formula. No change in the job-mix formula can be made without approval from the District Engineer.

Combining Raw Aggregates

40. Aggregates from the stockpiles, called the raw aggregates, must meet the Specification requirements and must be blended in such a way that the percentage of each size in the combined aggregate falls within the limits for the mix design approved by the District Engineer.

Settings of the cold feed depend on the gradations of the fine and coarse aggregates. After the gradations have been found by sampling and testing, every effort must be made to prevent segregation*. The aggregates must be handled and stored in stockpiles or bins so that segregation will not take place. Coarse aggregate must be added to a storage pile or removed from the pile in layers not more than 4 feet high. Aggregate bins must be constructed so that segregation will not take place in them. Prevention of segregation will help to keep the combined grading within the limits of the approved mix design.

The percentages, by volume, of the fine and coarse aggregates to be fed into the drier can be computed quite easily. The gradation of each type of aggregate will be known, and the percentage of the combined aggregates that should pass a No. 8 sieve will be fixed by the District Engineer. The gradations of the aggregates will give the percentage A, by weight, of fine aggregate that passes a No. 8 sieve and the percentage B, by weight, coarse aggregate that passes a No. 8 sieve. Let C be the percentage, by weight, of the combined aggregates that should pass a No. 8 sieve. To find the percentage X, by volume, of fine aggregate to be used in the combined aggregates fed to the cold feed elevator and drier, the steps are

Step 1. Subtract B from C.
Step 2. Subtract B from A.
Step 3. To find X, multiply the result in Step 1 by 100 and divide by the result in Step 2.

These steps can be shown by the formula

$$X = \frac{C - B}{A - B} \times 100$$

The percentage, by volume, of coarse aggregate in the combined aggregates fed to the cold feed elevator and drier is 100 - X.

To show how a fine aggregate and a coarse aggregate can be combined in a mix for an ID-2 binder course, an example will be given. The gradations of a fine aggregate and two types of coarse aggregates are shown in Table 1. It is desired to combine the fine aggregate and the No. 2B coarse aggregate so that 28.0 percent of the combined aggregates will pass a No. 8 sieve. In this case, A = 85.0, B = 2.5, and C = 28.0. Then

$$C - B = 28.0 - 2.5 = 25.5$$
$$A - B = 85.0 - 2.5 = 82.5$$

$$X = \frac{25.5}{82.5} \times 100 = 30.9, \text{ or say 31 percent,}$$

$$100 - X = 100 - 31 = 69 \text{ percent}$$

So, 31 percent of fine aggregate and 69 percent of coarse aggregate should be fed to the cold feed elevator and drier.

The percentages computed as just shown can be used to set the openings of the cold feed, from which the aggregates are carried by the cold feed elevator to the drier. The test results to be shown on the daily plant report are those from which the cold aggregate feeders are set for the day's production. Additional tests that may be made are usually check tests, and the results of these tests are to be recorded in the plant book.

TABLE 1 - Aggregate Gradations

Sieve Size	Fine Aggregate Percent Passing, By Weight	Coarse Aggregate No. 1B Percent Passing, By Weight	Coarse Aggregate No. 2B Percent Passing, By Weight
200	5.0		
100	10.0		
50	22.5		
30	38.8		
16	60.0		
8	85.0	5.0	2.5
4	98.5	20.0	8.0
3/8 in.	100.0	87.5	
1/2 in.		100.0	42.5
1 in.			95.0
1-1/2 in.			100.0

Gradation of Combined Aggregates

41. After the percentages of fine and coarse aggregates to be fed to the drier have been fixed, the percentage of the combined aggregates that will pass each size of sieve can be computed. These percentages are found to make sure that the combined aggregates being fed into the drier have very nearly the gradation required for the combined aggregates in the approved mix design. If the gradation of the aggregates in a completed batch of the mixture does not fall within the specified uniformity band on the gradation chart, either the aggregate proportions will have to be adjusted or some aggregate will have to be wasted by bin overflow.

To show how the percentages of the various sizes in the combined aggregates may be computed, the values for the mix considered before will be used. When 31 percent of the fine aggregate in Table 1 is combined with 69 percent of No. 2B coarse aggregate, the results are as shown in Table 2.

TABLE 2 - Gradation of Combined Aggregates

Sieve Size	Blend of 31% Fine Aggregate and 69% Coarse Aggregate			Percent Passing By Weight
200	0.31 x 5.0 = 1.6			1.6
100	0.31 x10.0 = 3.1			3.1
50	0.31 x22.5 = 7.0			7.0
30	0.31 x38.8 =12.0			12.0
16	0.31 x 60.0=18.6			18.6
8	0.31 x85.0 =26.4	+	0.69 x 2.5 = 1.7	28.1
4	0.31 x98.5 =30.5	+	0.69 x 8.0 = 5.5	36.0
1/2 in.	0.31x100.0 =31.0	+	0.69 x42.5 =29.3	60.3
1 in.	0.31x100.0 =31.0	+	0.69 x95.0 =65.6	96.6
1-1/2 in.	0.31x100.0 =31.0	+	0.69x100.0 =69.0	100.0

Drier

42. The Inspector-in-Charge at the plant must make sure that the drier is being operated properly. It must dry the aggregates thoroughly, (see Par. 11) and bring their temperature between specified limits. The amount of material fed to the drier must always be slightly less than that which can be thoroughly dried and heated, no matter how much moisture the aggregates contain. If the thermometer or pyrometer at the discharge chute of the drier is out of order, the producer can operate the plant for the rest of the day, provided that an accurate hand thermometer is used to check the temperature of the aggregate

frequently. If approved by the Laboratory, all or part of the dust collected during drying may be fed back into the hot aggregates at a uniform rate before they are screened into the bins over the mixer. A positive mechanical feed should be used for this purpose.

Screens Over Hot Bins

43. The plant screens over the hot bins must separate the aggregates, which were combined at the cold feed, into definite sizes with an efficiency of at least 85 percent. The hot bins must be built so as not to allow segregation of the aggregates in them, and must not be so large that the aggregate cools to below the mixing temperature by the time it is weighed out. Aggregates are usually put into three hot bins in the following size ranges (sizes correspond to laboratory sieve sizes): minus (passing) No. 8 material in the No. 1 bin; plus (retained on) No. 8 to minus 1/2 inch material in the No. 2 bin; and plus 1/2 inch to minus 1-1/2 inch material in the No. 3 bin. At least 85 percent of the material in the No. 1 bin must pass a No. 8 laboratory sieve; at least 85 percent of the material in the No. 2 bin must pass a 1/2-inch laboratory sieve, and not more than 15 percent can pass a No. 8 sieve; and 100 percent of the material in the No. 3 bin must pass the 1-1/2 inch laboratory sieve, and not more than 15 percent can pass the 1/2 inch sieve.

It is usually to the producer's advantage to use plant screens which have slightly larger openings than do the laboratory sieves. This practice is allowable as long as the efficiency of size separation is at least 85 percent. A slotted No. 6 screen may be used over the No. 1 bin, and a 5/8-inch screen over the No. 2 bin.

When 4 hot bins are used (as for a binder-course), the plant screens must be sized to place minus No. 8 material in the No. 1 bin; plus No. 8 to minus No. 4 material in the No. 2 bin; plus No. 4 to minus 1/2 inch material in the No. 3 bin; and plus 1/2 inch to minus 1-1/2 inch material in the No. 4 bin. Of the total material in bins 2 and 3 not more than 15 percent can pass the No. 8 sieve, and not more than 15 percent can be retained on the 1/2 inch sieve.

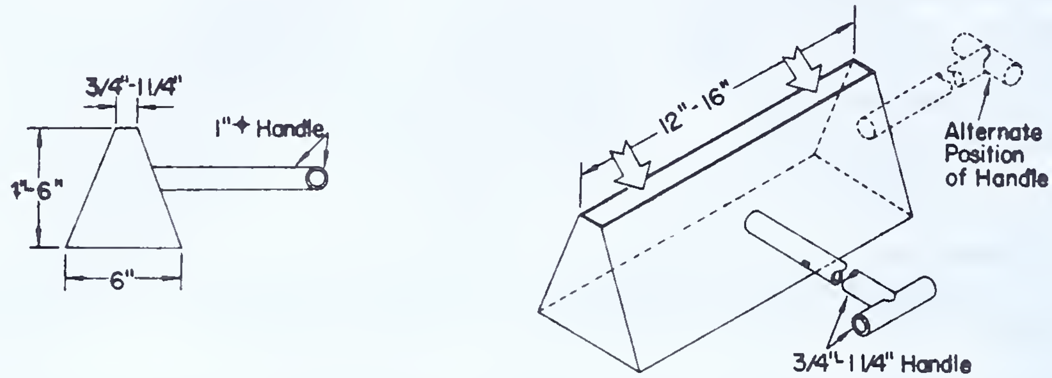
If the material in the bins does not meet these requirements, the plant cannot be permitted to send out hot mix for Department work until corrections are made. If too many coarse particles (material retained on the No. 8 sieve) are found in material taken from the No. 1 bin, either there are holes in the screens or there is overflow into that bin from other bins. Usually, trouble shows up in material taken from the No. 2 bin. If too much material is fed to the drier, some of the fine aggregates, which should go into the No. 1 bin, will ride on a thick layer of material on the screen and be carried over to the No. 2 bin. A much larger quantity of material will be carried over if the screen over the No. 1 bin is "blinded", that is, if some of the openings are closed by pieces of aggregate which are just the right size to stick in the openings and plug them up.

Because there is more trouble with the No. 2 bin, it should be checked frequently by taking out a representative sample and looking at it. If it seems that a considerable amount of fine aggregate is mixed in with the coarse aggregate, a check sieve test should be made.

When screens of the correct sizes are used, there usually is less trouble with the No. 3 bin. If fine aggregates is found in this bin, far too much material is being fed to the drier, or the screens are badly blinded.

Sampling Material From Hot Bins

44. There must be a safe way to get representative samples from each hot bin. To get a representative sample from Bin No. 1, a sampler must be used to catch the flow across the entire width of the gate opening. A sampler such as shown in the illustration, recommended by the Asphalt Institute, gives the best results.



Much of the finest material usually will be on the side of the bin nearer the hot elevator. For this reason, it is usually best to push the sampler into the stream of material flowing from the opened gate at right angles to the direction of flow of material across the screens. If this is not done, the sampler tends to become filled with either fine or coarse material while it is being pushed in. When the sample is being taken, the plant should be operating normally and the bin gate should be opened fully.

The sampler should have high sides, so that coarse material will not roll off it during sampling. A sample should never be taken with a shovel or other unsuitable device, as the results of tests on the sample then will not show what is actually in the bin.

A sample that weighs from 20 to 50 pounds should be taken from the No. 1 bin. Unless a sample splitter* is used the whole sample should be dampened and thoroughly mixed, and should then be quartered until the volume left is of testing size. At least one sample must be taken in the morning and one in the afternoon. The plant technician employed by the plant operator must always check the Inspector's sampling and testing of material from all bins.

For sampling material from bins 2 and 3, a sampler like the one described for bin No. 1 should be used. Each sample should weigh between 35 and 75 pounds. A smaller amount may be tested, but it is usually better to run the entire sample through the mechanical shaker sieves, even if the sample has to be divided into two or three parts. At least one sample must be taken in the morning, and one in the afternoon.

Computing Hot Bin Percentages of the Combined Aggregates

45. The screening efficiency of the plant is based on the results of sieve tests made on samples from the hot bins. The test results shown on the Plant Report, Form 448, are also used to set the batch weights. Additional tests usually are check tests and are recorded in the plant book.

TABLE 3 - Gradation Based on Samples From Bins No. 1, No. 2, & No. 3

	Percent Passing, by Weight		
Sieve Size	Bin No. 1 Fine Aggregate	Bin No. 2 Intermediate Aggregate	Bin No. 3 Coarse Aggregate
200	5.6		
100	10.7		
50	24.2		
30	41.5		
16	64.4		
8	96.5	0.5	0.0
4	100.0	23.0	0.0
1/2 in.	100.0	92.4	6.7
1 in.	100.0	100.0	91.6
1-1/2 in.	100.0	100.0	100.0

The procedure for computing the percentage of the combined aggregates, by weight, to be taken from each of three hot bins is divided into three parts. In the first part is found the desired percentage of the aggregates in bins 2 and 3 only, that passes a 1/2 inch sieve. Here are the steps in this part:

Step 1. Find the percentage of total hot aggregates that has been screened into Bin No. 1. To do this, get from a table like Table 2, the percentage of the combined aggregates that passes a No. 8 sieve; and get from the gradation test of aggregate from Bin No. 1 the percentage of the aggregate in that bin which passes a No. 8 sieve. Multiply the first percentage by 100, and divide by the second percentage.

Step 2. Find the percentage of total hot aggregates that has been screened into bins 2 and 3 by subtracting the percentage in Step 1 from 100.

Step 3. Find the percentage of the total aggregates in bins 2 and 3 that passes a 1/2 inch sieve. To do this, get from a table like Table 2, the percentage of the combined aggregates that passes a 1/2 inch sieve. Subtract from this percentage the percentage found in Step 1.

Step 4. Multiply the percentage in Step 3 by 100, and divide by the percentage in Step 2.

To show the method by an example, the gradations in Table 2 and Table 3 will be used. From Table 2 the percentage of minus No. 8 material in the combined aggregates is 28.1. From Table 3 the percentage of minus No. 8 material in hot bin No. 1 is 96.5. By Step 1, the percentage of total hot aggregates screened into bin No. 1 is

$$100 \times \frac{28.1}{96.5} = 29.1$$

By Step 2, the percentage of total hot aggregates screened into bins 2 and 3 is

$$100 - 29.1 = 70.9$$

From Table 2 the percentage of minus 1/2 inch material in the combined aggregates is 60.3. By Step 3, the percentage of minus 1/2 inch material in bins 2 and 3, based on the total aggregate, is

$$60.3 - 29.1 = 31.2$$

By Step 4, the desired percentage of the aggregates in bins 2 and 3 only, that passes a 1/2 inch sieve is

$$100 \times \frac{31.2}{70.9} = 44.0$$

The second part of the procedure for computing the percentage of the combined aggregates to be taken from each hot bin is to find the relative percentages of materials to be taken from bins 2 and 3 by considering the material in those two bins passing a 1/2 inch sieve. The percentage A of minus 1/2 inch material in bin No. 2 will be known from the gradation of that material; and the percentage B of minus 1/2 inch material in bin No. 3 will also be known. The percentage C of the total material from these two bins that should pass a 1/2 inch sieve has been found in the first part of the procedure. The percentage X of the total material from bins 2 and 3 to be taken from bin No. 2 is found from the formula

$$X = \frac{C - B}{A - B} \times 100$$

To show the method by an example, the gradations given in Tables 1, 2, and 3 will be used. From Table 3, A = 92.4 and B = 6.7. From the first part of the procedure, C = 44.0. Then

$$C - B = 44.0 - 6.7 = 37.3$$

$$A - B = 92.4 - 6.7 = 85.7$$

$$X = \frac{37.3}{85.7} \times 100 = 43.5$$

Considering only the combined aggregates from bins 2 and 3, 43.5 percent will be taken from bin No. 2 and 100 - 43.5, or 56.5, percent from bin No. 3.

The third and last part of the procedure is to find the percentage of the combined aggregates to be taken from each hot bin by considering the material in the bins passing a No. 8 sieve. The percentage to be taken from bin No. 1 is computed in this way: The percentage A of minus No. 8 material in bin No. 1 will be known from the gradation like that in Table 3. From that table, A = 96.5. The percentage B of minus No. 8 material in bins 2 and 3 combined can be found from the gradations like those in Table 3 and the percentages

found in the second part of the procedure. In the example used here,

$$B = 0.435 \times 0.5 + 0.565 \times 0.0 = 0.2$$

As stated before, the percentage C of minus No. 8 material in the combined aggregates will be fixed by the District Materials Engineer. In the example being worked out, C = 28.0. The percentage X of the total aggregates to be taken from bin No. 1 is found from the formula

$$X = \frac{C-B}{A-B} \times 100$$

In the given example,

$$C - B = 28.0 - 0.2 = 27.8$$

$$A - B = 96.5 - 0.2 = 96.3$$

$$X = \frac{27.8}{96.3} \times 100 = 28.9$$

The percentage of total aggregates to be taken from bins 2 and 3 combined is 100 - 28.9 = 71.1. The percentage to be taken from bin No. 2 is

$$71.1 \times 0.435 = 30.9$$

and the percentage to be taken from bin No. 3 is

$$71.1 \times 0.565 = 40.2$$

As a check, 28.9 + 30.9 + 40.2 = 100. The computed proportions of the aggregates from the three hot bins that should produce the design mix are 28.9 percent from bin No. 1, 30.9 percent from bin No. 2, and 40.2 percent from bin No. 3. If the gradations of the aggregates screened into the three bins are as shown in Table 3 and the aggregates are combined in the computed proportions, the gradation of the combined aggregates should fall within the uniformity band established in the approved design. If the combined grading does not fall within the uniformity band, at any time during production, the plant operator must be notified at once and corrections made so that the combined grading will again fall within the uniformity band.

<u>Checking Gradation of Combined Aggregates</u>

46. Using the proportions of hot aggregates from bins 1, 2 and 3 worked out, the composite grading of the combined hot aggregates can be checked as shown in Table 4. These results should agree with those in Table 2.

TABLE 4 - Gradation of Combined Aggregates From Hot Bins

Sieve Sizes	Bin No. 1 (28.9%)	Bin No. 2 (30.9%)	Bin No. 3 (40.2%)	Percent Passing by Weight
200	0.289x 5.6 = 1.6			1.6
100	0.289x 10.7 = 3.1			3.1
50	0.289x 24.2 = 7.0			7.0
30	0.289x 41.5 = 12.0			12.0
16	0.289x 64.4 = 18.6			18.6
8	0.289x 96.5 = 27.9	+ 0.309x 0.5 = 0.2		28.1
4	0.289x100.0 = 28.9	+ 0.309x 23.0 = 7.1		36.0
1/2 in.	0.289x100.0 = 28.9	+ 0.309x 92.4 = 28.6	+ 0.402x 6.7 = 2.7	60.2
1 in.	0.289x100.0 = 28.9	+ 0.309x100.0 = 30.9	+ 0.402x 91.6 = 36.8	96.6
1-1/2 in.	0.289x100.0 = 28.9	+ 0.309x100.0 = 30.9	+ 0.402x100.0 = 40.2	100.0

Batch Weights

47. If the composite grading of the hot aggregates falls inside the uniformity band, batch weights can be computed. Assume that the asphalt content of the mix here used is 4.7 percent, by weight. The percentage of the total weight of a batch to be taken from each hot bin can be computed this way:

The mix consists of 4.7 percent of asphalt and 100-4.7, or 95.3, percent of aggregates. The percentages of aggregates to be taken from the three bins are:

Bin No. 1, 95.3% x 0.289 = 27.5%

Bin No. 2, 95.3% x 0.309 = 29.5%

Bin No. 3, 95.3% x 0.402 = 38.3%

Assume that the total weight of one batch is 4,000 pounds (2 tons). The weight of each material then is:

Bin No. 1, 4000 x 0.275 = 1100 lb

Bin No. 2, 4000 x 0.295 = 1180 lb

Bin No. 3, 4000 x 0.383 = 1532 lb

Asphalt, 4000 x 0.047 = 188 lb

Total = 4000 lb

The bin weights for aggregate are usually given to the man who actually weighs the material from the bins into the batch in accumulative weights. This means in increasing order of weight, the same as the weights will appear on the aggregate scale. To prevent fine aggregate leaking from the weigh hopper, or being dropped first to the bottom of the pugmill, it is usually best to start by weighing out the required amount of one of the coarser sizes of aggregate. The scale weight slip for the weights given above might look like this:

Bin No. 3	1532 pounds
Bin No. 2	2712 pounds
Bin No. 1	3812 pounds
Asphalt	188 pounds
Total Batch	4000 pounds

Computing Percentages for ID-2 Wearing Course

48. The control procedure and computations for a wearing-course mixture are similar to those for a binder-course mixture. As an example, the work will be shown for combining the fine aggregate and the No. 1B coarse aggregate in Table 1 so that 45.0 percent of the material will pass a No. 8 sieve.

The percentage X, by volume, of fine aggregate in the combined aggregates fed to the cold elevator can be found as for a binder-course mixture. In the example considered here, A = 85.0, B = 5.0, and C = 45.0. Then

$$C - B = 45.0 - 5.0 = 40.0$$

$$A - B = 85.0 - 5.0 = 80.0$$

$$X = \frac{40.0}{80.0} \times 100 = 50.0$$

$$100 - X = 100 - 50.0 = 50.0$$

The cold-elevator feed should be set to mix 50 percent of fine aggregate with 50 percent of No. 1B coarse aggregate.

The next step is to prepare a table like Table 2 showing the gradation of the combination of 50 percent of fine aggregate and 50 percent of No. 1B coarse aggregate. The Inspector then takes samples from the hot bins and determines the gradation of each bin. In this example, only two hot bins will be needed, and the gradations given in Table 5 will be used.

TABLE 5 - Gradations of Samples From Bins No. 1 and No. 2

Sieve Size	Percent Passing, by Weight Bin No. 1	Bin No. 2
200	5.0	
100	11.3	
50	33.0	
30	49.4	
16	74.8	
8	97.8	7.4
4	100.0	26.8
3/8 in.	100.0	94.9
1/2 in.	100.0	100.0

The procedure for finding the percentage X, by weight, of combined hot aggregates to be taken from bin No. 1 is similar to that for finding the percentage of fine aggregate fed to the cold elevator. Again, the percentages A and B are based on the minus No. 8 material. From Table 5, A = 97.8 and B = 7.4. Then, since C = 45.0

$$C - B = 45.0 - 7.4 = 37.6$$

$$A - B = 97.8 - 7.4 = 90.4$$

$$X = \frac{37.6}{90.4} \times 100 = 41.6$$

$$100 - X = 100 - 41.6 = 58.4$$

When 41.6 percent of aggregate from bin No. 1 is combined with 58.4 percent of aggregate from bin No. 2, the composite gradation is as shown in Table 6.

TABLE 6 - Gradation of Combined Aggregates From Hot Bins

Sieve Size	Bin No. 1 (41.6%)		Bin No. 2 (58.4%)	Percent Passing By Weight
200	0.416 x 5.0 = 2.1			2.1
100	0.416 x 11.3 = 4.7			4.7
50	0.416 x 33.0 = 13.7			13.7
30	0.416 x 49.4 = 20.5			20.5
16	0.416 x 74.8 = 31.1			31.1
8	0.416 x 97.8 = 40.7	+	0.584 x 7.4 = 4.3	45.0
4	0.416 x 100.0 = 41.6	+	0.584 x 26.8 = 15.7	57.3
3/8 in.	0.416 x 100.0 = 41.6	+	0.584 x 94.9 = 55.4	97.0
1/2 in.	0.416 x 100.0 = 41.6	+	0.584 x 100.0 = 58.4	100.0

If the combined grading falls inside the uniformity band, the percentage of aggregate to be taken from each bin can be computed. Assume that the asphalt content of the mix here used is 6.4 percent, by weight, and the weight of aggregates in the mix is 100 - 6.4 = 93.6 percent. The percentages of aggregates to be taken from the bins are:

Bin No. 1, 93.6% x 0.416 = 38.9%

Bin No. 2, 93.6% x 0.584 = 54.7%

Assume that the total weight of each batch is 4000 pounds. The weight of each material then is:

Bin No. 1, 4000 x 0.389 = 1556 lb

Bin No. 2, 4000 x 0.547 = 2188 lb

Asphalt, 4000 x 0.064 = 256 lb

Total = 4000 lb

Responsibility of Paving Inspector

49. An asphalt pavement is built for the benefit of the traveling public. The motorist is paying for the road and is paying the Inspector to see that he get construction of high quality. The motorist judges a road by its smoothness and surface appearance. Bumps, an uneven ride, or the early appearance of cracks, potholes, or raveling joints are criticized. It is the responsibility of the Inspectors on the laydown operation, by enforcing the

Specifications, to see to it that the best possible riding surface is obtained, and that every foot of the pavement is free from defects that require early maintenance.

The Inspectors of the laydown and rolling operations are important members of the inspection team. They take over after a great deal of money and effort have been spent to check the quality of materials in the paving mixture and to make sure that it was produced in such a way as to give the best possible pavement. Whether or not this result is obtained depends a great deal on the attitude of each Inspector on the job. He cannot act merely as an observer. He must take an active interest in the construction in order to get the Contractor's workmen to produce a road that will meet every requirement of the Specifications and will have a smooth riding surface.

The Inspector must check each part of the finished surface for smoothness. He must also check many details to make sure that the quality provisions of the Specifications will be met when check tests are made. He is not expected to tell the Contractor what to do or how to do it, but he must be familiar enough with good workmanship and the proper operation of equipment to warn the Contractor that unsatisfactory results are being obtained.

When laydown begins, the Paving Inspector should observe the appearance of the mat carefully, particularly at the sides of the lane next to the joints, under the supervision of the Inspector-in-Charge. If there is any great change in the appearance of the mat during future laydown, the Inspector should get in touch with his superior at once. Also, whenever the Paving Inspector notices any unusual or unsatisfactory conditions in the laydown and rolling of bituminous concrete, he should contact the Plant Inspector.

In order that the Plant Inspector will be able to complete his daily reports, the Paving Inspector must send him a report that lists by stations the locations of the pavement laid during the day; the type (surface course or binder course); the square yards covered; and the amount of bituminous mixture that was rejected. He should also list any changes from the usual width and depth of pavement.

Placing Bituminous Concrete

50. Since nearly all of the bituminous concrete surface courses being placed in the State are made of ID-2 mixtures, the detailed instructions that follow apply to surface courses of this type. Where changes are necessary for other types of bituminous concrete surfaces, they are noted.

The Specifications limit the temperature at which asphaltic concrete may be placed. Proper compaction depends on rolling the mixture while it is hot enough to allow the asphalt-coated particles to be pressed closely together. When a thin layer of asphaltic concrete is placed on a cold surface, the bottom of the layer cools quickly. If the air is also cold, the upper surface of the layer is chilled at the same time. When the layer is rolled under these conditions, the top and bottom parts of the layer usually will have more voids, and larger voids, than asphaltic concrete placed during warm weather.

The average density will then be low. A more important result is that water may get into these voids and freeze; if it does, the aggregate will loosen and the pavement will ravel out or have potholes. Raveling* often starts at the longitudinal joints in asphaltic concrete surfacing placed during cold weather. If it is necessary to place asphaltic concrete during cold weather, the work should be done during a period that is expected to be followed by at least 2 weeks of warm weather. During this time traffic will compact and seal the surface. This action will help to keep the water out and reduce the danger of raveling. Rolling with heavy, self-propelled rubber-tired rollers, that exert a contact pressure of at least 90 psi on the pavement, will produce the same result if the pavement is rolled when it is warm. Such rolling should be permitted, and may be required.

Preparation of Base

51. Before the binder course is placed, the Inspector-in-Charge on the project must inspect the base to see that it is in proper condition to receive the binder-course mixture. Any needed patching, faulty drainage, faulted joints, or other defects which have been overlooked in the preliminary inspection must be called to the attention of the Inspector-in-Charge. The base must be firm and stable at all points. Asphaltic mixtures have some flexibility. However, if the mixture is placed on a surface which deflects (moves downward) even slightly under load, the millions of deflections caused by traffic eventually will cause the pavement to crack.

The base ahead of the paving operation should be inspected carefully and, if necessary, tested with a heavy roller. Some types of bases, although they were originally compacted to Specification density, lose this density before paving begins. Sometimes the application of a prime coat, where used, will cause the base to "fluff up"; if this happens, the base must be re-rolled before a binder-course mix is placed. Some areas of the base may have absorbed water because of poor drainage. Any areas of base which become rutted or yield markedly under a heavy roller should be reported to the Inspector-in-Charge.

All unsuitable patches, excess crack or joint filler, and any surplus bituminous material must be removed from the surface of existing pavement to be used as a base. All low spots in the base that are 1 inch or more deep must be patched with material for a binder course, and this material must be thoroughly compacted, ahead of the paving operation. Before the arrival of binder-course mixture, the base must be cleaned of all loose and foreign materials. If the binder course is to be placed on an aggregate base, loose or matted fine material on the base must be removed first. Care should be taken in removing such material not to disturb bond of the aggregate in the upper part of the base by removing the screenings (the fine crushed stone and dust used to choke the coarse aggregate) below the tops of the aggregate pieces. When excess fine material has been removed properly, only the tops of the aggregate pieces in the upper part of the base will be exposed and the pieces of aggregate will still be solidly embedded in the base. The binder course can be laid only on a dry, firm base and in suitable weather.

The riding quality of the surface course depends to a great degree on the proper construction of the base course. Where an old or new base is rough or uneven, provision should be made for placing a leveling course* of material

for a binder or wearing course between the base and the regular binder course.

Preparation of Vertical Contact Surfaces

52. Where a vertical face of a curb, gutter, existing pavement, or other structure will be in direct contact with a bituminous paving mixture, that face must first be painted with a thin, uniform coating of Class BM-1 or Class A-1 asphalt cement to provide a closely-bonded watertight joint.

Tack Coat

53. The surfaces on concrete, brick or bituminous pavements or base courses which are to be surfaced or resurfaced must, when required, be prepared by the application of a tack coat. A tack coat is a very thin, uniform application of bituminous material. The purpose of a tack coat is to get a dust-free surface to which the new course will bond firmly. At the bottom of a steep grade or on approach to a traffic light, the asphaltic surfacing should be tightly bonded to the underlying surface so that it will not push up in waves.

If great care is not taken in applying a tack coat, it may do more harm than good. A heavy tack coat will act as a lubricant between the base and the surface course, and will cause movement instead of preventing it. There is also danger of a heavy tack coat bleeding through the new surface to create a soft, slippery pavement.

The bituminous material for a tack coat may be asphalt cement of Class A-1 or Class BM-1; asphaltic cement cut-back of Class C-1, NC-1, C-2, NC-2, CE-1, CE-3, P-1 or NP-1; or asphaltic emulsion of Class F-3 Type II. Class A-1 and Class BM-1 are seldom used since it is hard to get a thin uniform tack coat with these materials.

Enough bituminous material should be used for a tack coat to leave from 0.05 to .07 gallon on each square yard of the area to be paved. After the tack coat has cured, it should be about as thick as a coat of paint. It is better to have too little tack coat than too much. If the District Construction Engineer approves, a uniform sprinkling (called speckling) of the old surface may be enough; with some types of surfaces, a tack coat is not needed.

The temperature of a bituminous material must not be higher than the limit given in Bulletin 25 for the particular material used. When the rate of application is .05 to .07 gallon per square yard, the surface-coating will be very thin. The only practical way of applying this thin coating uniformly is to use equipment which produces a fog spray. A regular truck-mounted motor-driven distributor is not practical for applying a tack coat. If use of equipment of this kind is permitted, it must be specially equipped to apply a satisfactory tack coat. Any area missed by the sprayer must be properly treated with bituminous material applied with a hand spray. Extra bituminous material on any area must either be covered with enough dry sand to blot up the excess or be removed. Before the bituminous concrete is placed, the tack coat should be allowed to cure without being disturbed until inspection shows that all of the solvent in the material has evaporated. An emulsion tack coat may be used when traffic must be carried during paving. The surface treated with a tack coat has to be protected until the binder course or surface course has been

placed. All damaged areas must be repaired before the bituminous concrete is placed. The surface of a binder course* has to be tack-coated when the Assistant District Construction Engineer decides that a coat is necessary.

Machines for Spreading and Finishing

54. Spreading and finishing equipment must be approved by the Laboratory before it can be used.

A finishing machine (paver) must be designed and operated so that material does not collect and stay on the sides of the receiving hopper. Material that collects there cools off and is unfit for use, and must be rejected. The Contractor must furnish an operating manual for the finishing machine used. That manual must be available at all times, so the Inspector can get information about the correction,adjustment,and operation,of the machine.

The Contractor's men operate the finishing machine and make all adjustments. The Inspector must never operate or adjust any of the Contractor's equipment. However, he must know enough about the equipment to be sure that it has been properly adjusted and is capable of spreading and finishing the mixture properly. A screed* which has material sticking to its contact (lower) surface or which is warped from over-heating will not produce pavement of acceptable quality. If the tamper bars* are not adjusted properly, particles of coarse aggregate will be dragged along by the screed; a poor surface texture will result. If the tracks are not tightened properly or if the nuts on the screed adjustment screws are worn, the finisher will produce waves in the surface. The Inspector must know the kinds of surface defects that are caused by improper adjustment or operation of the finisher, and must refuse to accept poor results. Little hand work behind the finisher should be required. It is not good practice to scatter or "fan" loose material on the finished mat to improve poor texture* produced by a machine that needs repair or adjustment.

If there is a defect in the mat* behind the finisher, such as a spot with too much asphalt, uncoated aggregate, or having lower density than the rest of the mat, the material in that area should be removed cleanly with a shovel for the entire depth of the mat. Hot material from the hopper of the finisher should be carried back with shovels and placed in the hole in the mat. The workmen must not be permitted to throw material into the hole from the edge of the lane. Any required smoothing must be done with lutes. The use of rakes on a bituminous concrete should never be permitted, except to loosen a compacted surface.

Steel roller wheels must be tested with a straightedge in order to see if they are flat for the entire width of the roll. If a roller produces a wavy surface, it should be checked for worn bearings or improper ballasting. The use of defective rollers must not be permitted.

When the use of pneumatic (rubber) tired rollers is allowed or specified, they should be so ballasted and the tire pressure should be so adjusted that they will compact the still-warm mix without displacing it. A slight marking or grooving of the mix is normal and is a sign of good compaction.

Hand Tools

55. The use of rakes to level or move mixed bituminous concrete back of the paver results in segregation. For this reason, only lutes or rakes with covered teeth are to be used at the paver and for hand finishing.

Tamping irons used to compact the edges of the binder course or wearing course must be heavy enough to compact the edges to the same density as the rest of the pavement. They must be designed to form an edge as nearly vertical as possible. The use of a sealing iron, which seals the material by heat, is required by the Specifications.

Equipment used for heating hand tools should be designed so that the tools will be hot enough to permit the asphalt to be removed from them, but not so hot that there is danger of burning the material on which they are being used. In any case, the temperature of the tools, when in use, must not be greater than the temperature of the material being placed. Hand tools must be cleaned by heating and scraping; petroleum oils or solvents are not to be used. The heating equipment should be kept away from the paving equipment and the area to be paved.

Straightedges, 10 feet and 16 feet long, must be furnished by the Contractor and kept readily available to test the finished surface. They are most conveniently carried on brackets attached to the paver. A 16-foot straightedge is to be used in all places except on vertical curves, where a 10-foot straightedge may be used.

Edges of Lanes

56. The lanes of a binder course must be placed so that the longitudinal joints will not fall directly beneath the longitudinal joints in the wearing course. An offset is usually obtained by using a cut-off shoe* on the paver screed to make the first lane of the binder course narrower than the lane width planned for the surface course. It is also possible to use a screed extension to make the binder-course lane wider. Either method makes it possible to have a longitudinal joint in the wearing course at the centerline of the pavement, where it will be covered by the traffic stripe.

To get a true edge on a lane, the paver operator must have a line to follow. Such a line is parallel to, but offset from, the centerline of the pavement and may be set on either side of the paver. However, it is usually best to set the line near the centerline on two-lane pavement and near the inside edge of the lane when the pavement is to be more than two lanes wide. The line may be set by measuring over the required distance from the centerline points and driving stakes in the shoulder, or by driving nails into, or making marks on, the pavement and base.

Usually the line is set about 1 foot outside the edge of the lane so that the paver operator can easily see the guide attached to the paver.

When a leveling course is being laid, the guide line for the edge of a lane should be set to both line and grade. Because it takes some distance to show the effect of changes in the screed controls, the screed operator must look ahead and judge the distance to the line from the existing grade about 10 or

15 feet ahead of the screed. A reasonable amount of screed adjustment may help to improve the grade when a leveling or binder course is being laid. After the first lane has been placed, the guide line set for it can be used to set the line for the next lane, and so on. Offset distances should be measured carefully so that the guide lines are kept exactly parallel to the centerline. The paver should be operated so as to follow the guide line closely. If is is not, it will be necessary to trim the edge of the lane to a straight line, in order to get a satisfactory longitudinal joint*.

Starting Section of Wearing Course

57. If possible, a lane of wearing course* should be started so that the finisher will move away from some surface that is at the correct grade, such as an existing pavement or a bridge deck. At such a location, the spreader should be backed up until the leading edge of the screed is behind the line where the wearing course is to begin. The screed should rest on wood or metal strips which are about one-fourth as thick as the wearing course will be after it has been compacted (3/8 inch thick for a 1-1/2 inch course). When a lane is started at any other location, the screed should be supported on wood strips which are about 1-1/4 times as thick as the compacted wearing course will be (1-7/8 inch for a 1-1/2 inch course).

Operation of Trucks (See VIII - 40B,C)

58. Care must be taken in backing a truck up to the paver to make sure that it is spotted properly; otherwise, the paver may be thrown off line when it starts. A truck must never be backed against the paver; it must stop a few inches away, with the rear wheels at equal distances from the rolls at the edge of the hopper.

The Inspector-in-Charge on the paving operation must be sure that no truck-load of material is accepted unless it is accompanied by an original (white) copy of Form 4128. The Paving Inspector (on contract work) or the maintenance foreman (on Department work) who receives the material must fill in the blanks at the bottom of the form. On contract work, the forms are kept on file at the project office and turned in with the other records at the end of the job. On maintenance work, the foreman sends the original copies to his Maintenance Superintendent.

When placed, the temperature of the mixture must not differ from that set by the District Engineer and District Materials Engineer by more than 15 degrees F. The Inspector will need a thermometer to measure the temperature of the first truck-load delivered, and about every third load after that. A thermometer is a delicate instrument, which must be used carefully. To measure the temperature, the thermometer should be pushed into the load in the truck at different points to a depth of at least 5 inches. One of these points may be at a hole in the side of the truck near one end of the middle third of the truck's length and 10 inches from the floor. To prevent loss of heat from the surface of the load, the covering on the load should be left in place until just before the truck is backed up to the paver.

Delivery of material to the paver should be at a uniform rate. The rate at which the material is delivered should not be greater than the capacity of the paving and rolling equipment being used. Best results are obtained when

the paver is operated slowly enough to always have a truck of material waiting so that the paver does not have to stop. If the paver is operated at a high speed and runs out of material before the next truck arrives, the material already laid will cool off. The material laid after the paver starts up again will have a higher temperature. As a result, there will not be a uniform rolling condition at the point where the paver stopped, and it will be difficult to complete the pavement properly. If paving begins at a relatively slow rate at the start of each day's laydown, the trucks will be well spaced and plant operations will be more nearly uniform. The table below shows about how fast the paver must travel at a steady rate to spread the plant out-put in a 12 foot lane.

	Plant Production		
Compacted Thickness	100 ton/hr.	150 ton/hr.	200 ton/hr.
1 inch	24 ft./min.	36 ft./min.	48 ft./min.
1-1/2 inch	18 ft./min.	27 ft./min.	36 ft./min.
2 inch	12 ft./min.	18 ft./min.	24 ft./min.

Operation of Paver (See VIII - 40A)

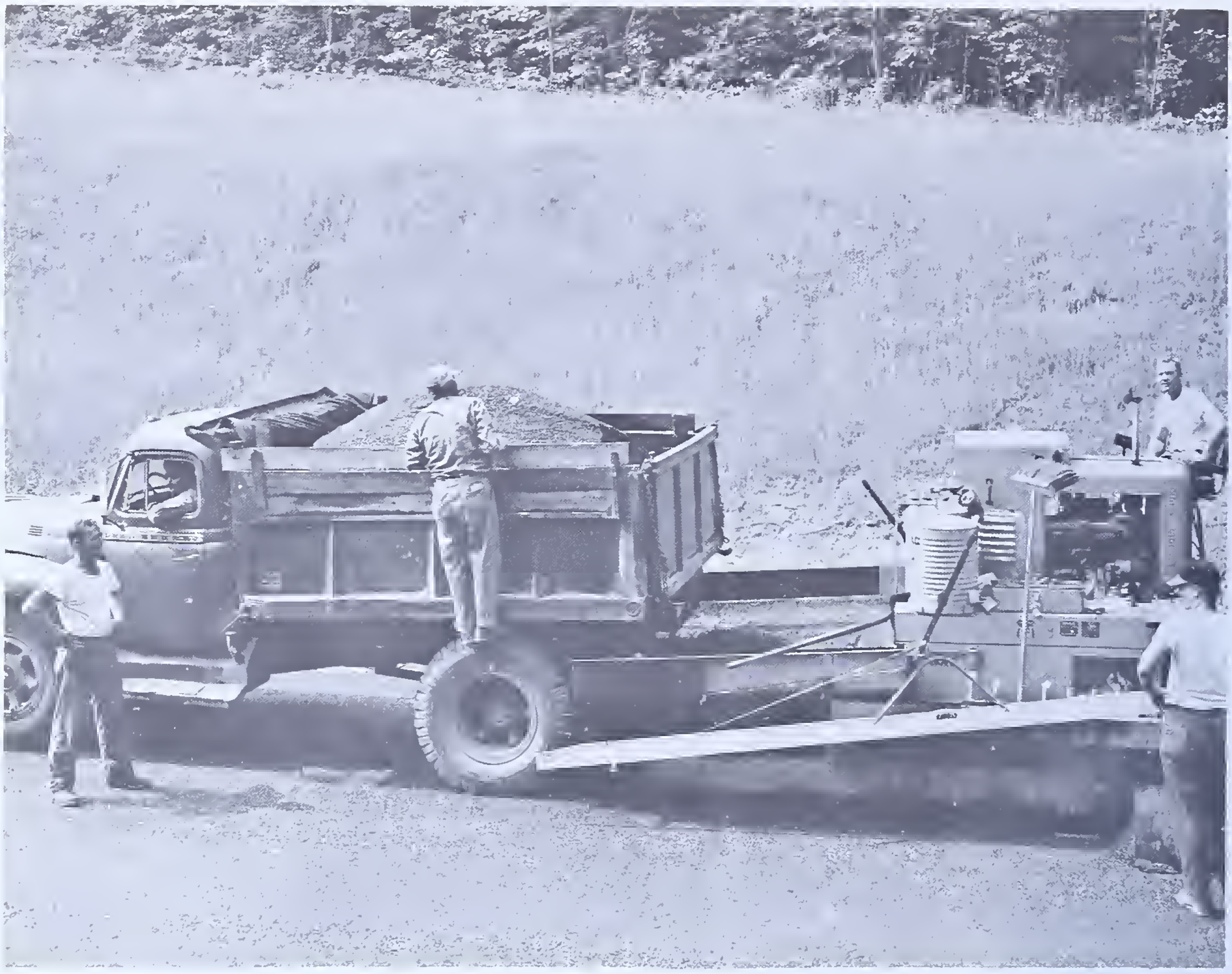
59. As soon as the first load of mixture has been spread, the texture of the unrolled surface should be observed to see if it is uniform. If the texture of the surface is not uniform, the adjustment of the screed, tamping bars, feed screws, hopper feed, and other elements of the paver should be checked. Any necessary adjustments should be made by the Contractor at once.

Segregation of materials may be the cause of non-uniformity. Segregation may come from faulty mix design, incorrect proportioning of materials, improper plant operation, or careless truck loading or unloading. The Inspector-in-Charge must be quick to recognize any trouble of this kind, and should stop the work until the cause of the trouble has been found and corrected.

It is particularly important that the edges of the lane be straight and that the mixture has the same texture at the edges as at the center. If there is too much coarse aggregate at the edge of a lane or if the edge is not true and straight, that edge will have to be lined and cut back before the lane next to it is placed. This step is necessary to get good density at the longitudinal joint and a smooth appearance.

After the material from the first truck or two has been spread, the Contractor's foreman and the Paving Inspector should check the depth of unrolled material that has been placed. They should also get the truck tonnage and the number of square yards laid, and compute the number of square yards per ton. The thickness of the uncompacted material may be checked by working the end of a folding rule or scored putty knife down through it to the surface of the course on which it was laid. A better way, however, is to probe with a nail driven part way into the end of a broom handle so that the length of nail left sticking out is the same as the desired thickness of the unrolled mat. This measurement should be made at several points. Usually, the thickness of the unrolled mat should be about 25 percent greater than the required compacted thickness, or about 1-7/8 inches for a 1-1/2 inch thickness of compacted mat.

Placing Bituminous Concrete



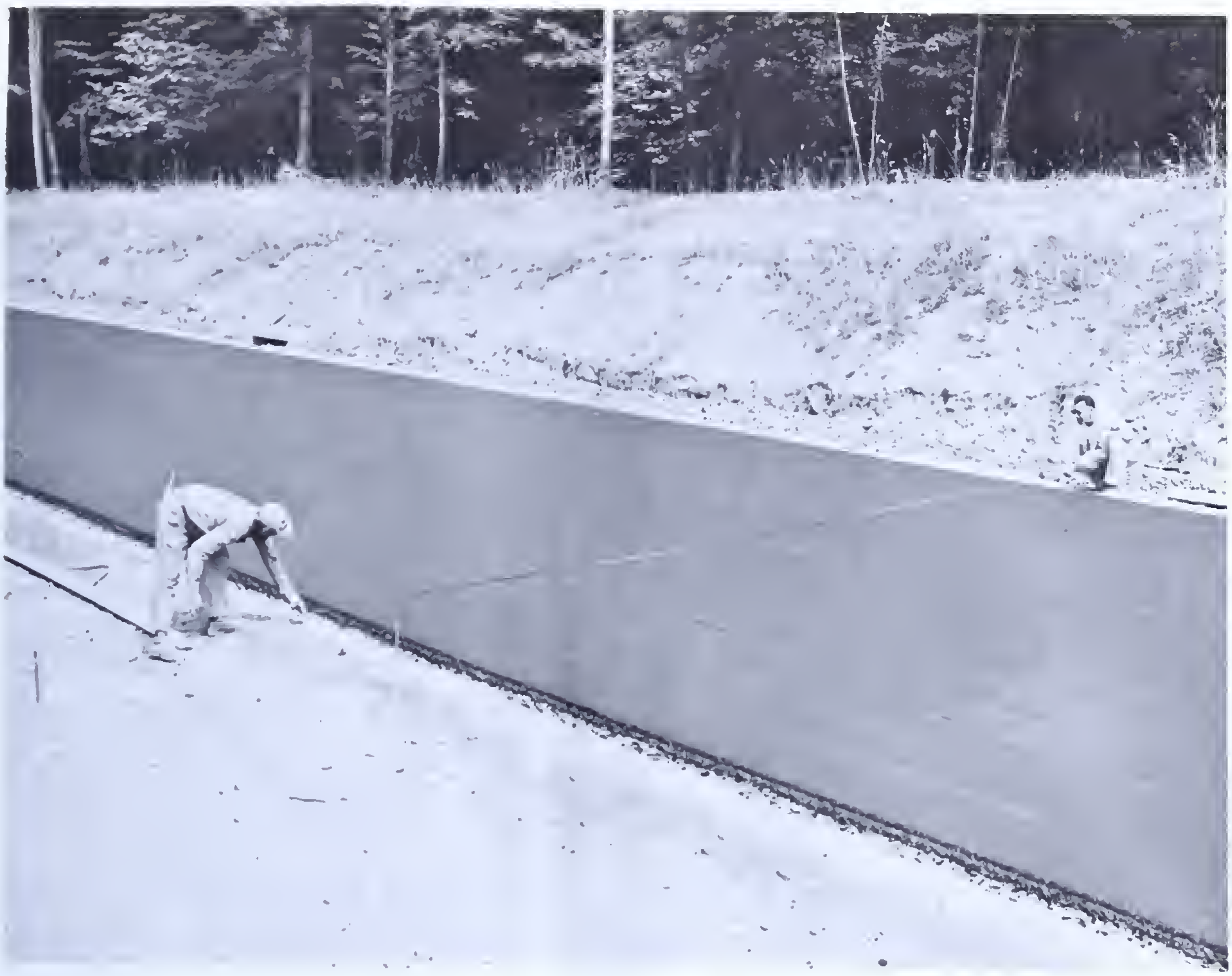
Checking Temperature

Truck Operation

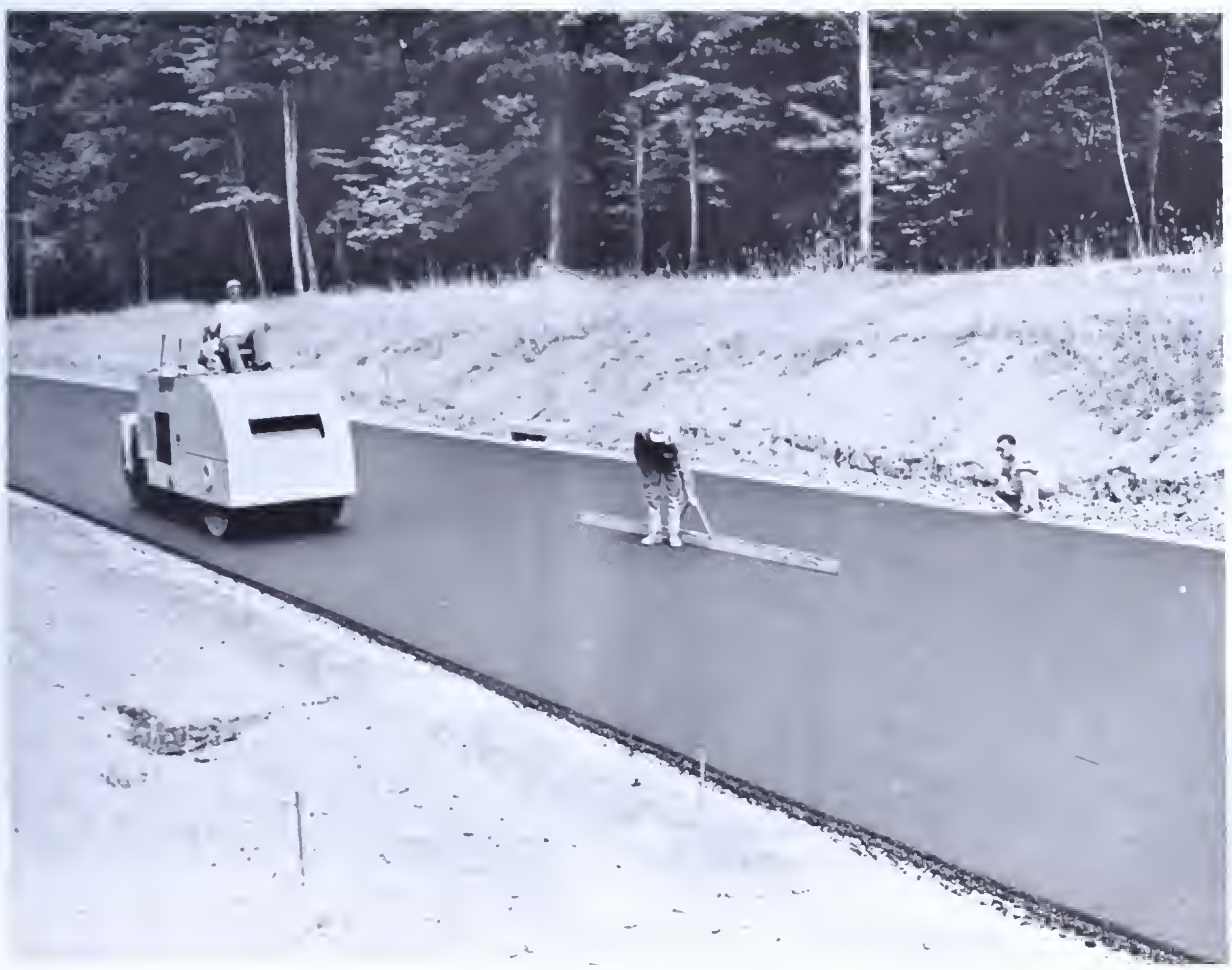
Guide Line

Truck-Cover on

Checking Mat Thickness



Chaining Pavement



Straight Edging

Compacting Wearing Course

Rolling longitudinal Joint

Finish Rolling

Checking Thickness of Mat (See VIII-40D)

60. The thickness of an unrolled mat of bituminous concrete needed to give a specified compacted thickness must be determined by trial. If the uncompacted thickness seems to be about right, a check can be made by considering the length of pavement covered by a ton of the mixture and using Table 7. The table shows, for various lane widths and compacted thicknesses, the approximate distance that a ton of material should cover.

TABLE 7 - Approximate Distance, in Feet, Covered by 1 Ton of Bituminous Concrete

Lane Width (Feet)	Compacted Thickness (Inches)						
	1/2	3/4	1	1-1/2	2	2-1/2	3
8	41.6	27.8	20.9	13.9	10.4	8.4	6.9
9	37.0	24.7	18.6	12.3	9.2	7.4	6.2
10	33.3	22.2	16.7	11.1	8.3	6.7	5.6
11	30.3	20.2	15.2	10.1	7.5	6.1	5.1
12	27.8	18.5	13.9	9.2	6.9	5.6	4.6

The distance given in the table for a given width and thickness is based on average conditions and may not be exactly right for a particular job. After the material is rolled, the thickness should be checked at several points by cutting holes through the layer to the underlying surface. The holes can be made with an axe or a hammer and chisel. The thickness at any point should be found by placing a short straightedge across the hole and measuring from the lower edge of the straightedge to the underlying surface.

It is not possible to have the same thickness of a surface course at all points and, at the same time, have a good riding surface, unless the top of the course on which the bituminous concrete was laid is perfectly smooth, like a table top. Since the surface of any course in a pavement has some waves with high and low spots, more material is usually needed to give a required minimum thickness than is shown by the table.

After repeated measurements on the job have shown that 1 ton of material will cover a certain length of lane with the required minimum thickness, this length should be used for checking the laydown. Frequent checks of the compacted thickness should be made, because changes in the mix or other factors may change the length of lane that can be covered to the minimum required thickness by 1 ton of material. A sure way to produce a rough-riding, wavy pavement is to permit the screed man to constantly adjust the controls that regulate the thickness of a surface course while it is being laid. When a surface course is being laid and paving is moving ahead at a uniform rate, these controls should be moved only slightly and the machine should travel at least 15 feet before the result of the adjustment is checked and the control moved again.

Trimming Edges of Lane

61. To get true edges on a lane, the paver must follow the guide line very closely. If the operator is careless, or if the paver is pushed off line by a truck which was not lined up when backed against it, the lane will have wavy edges. These edges must be made straight behind the paver by hand trimming. Material trimmed off must be thrown away. The edge of a lane must always be set up* with a lute so that the edge is nearly vertical. To get good results the end of the lute handle should be held about 30 inches from the ground. Any loose material left at the edge of the lane should be pulled back with the lute and thrown away.

The edge of each lane next to the shoulder must be compacted with a small hand tamper to seal the edge and give it the same density as the rest of the lane. If the mix moves during rolling, this hand tamping will have to be done again after final rolling. Unless another lane is to be laid against the inside edge while it is still hot, this edge also should be tamped. If the edge gets cold while the material is still loose, it will be impossible to get a longitudinal joint that has the density required to make it watertight.

Hand Spreading and Finishing

62. Spreading and finishing bituminous concrete with hand tools may be permitted by the Specifications or Special Provisions of the Proposal in a small area where it is not practical to use mechanical equipment. If mechanical finishing equipment is not used, approved steel or wooden forms must be set and rigidly supported. The mixture must be placed and spread carefully by experienced workmen. Care must be taken to prevent segregation.

The mixture must be piled outside the area on which it is to be spread, or placed on dumping plates. It is then spread with shovels in a loose layer so it will have the required depth after compaction. Measuring blocks, strips, and side forms must be used to help in getting the proper grade and cross section. Before being spread, all the material must be thoroughly loosened. It should then be spread evenly by lutes or covered rakes (rakes with the tines entirely covered by attached metal plates). Any lumps that do not break down easily must be thrown away.

Before rolling begins, the surface must be checked with templates and straightedges, and brought to the correct grade and cross section. A greater allowance must be made for the reduction of thickness during compaction when the material is spread by hand than when it is placed with a paver.

Compacting Binder and Wearing Courses (See VIII - 40 F,G)

63. The main purpose of rolling is not merely to produce a smooth surface but to compact the material to a high density. A paving mixture for a surface course is designed to have a low percentage of air voids* when the pavement is fully compacted. Rolling with steel-wheeled rollers will reduce the voids to nearly the final volume. The voids are further reduced by rubber-tired rollers where used, or by traffic. Any area which has too high a percentage of voids (more than about 6 percent by volume) after rolling is com-

pleted is very apt to give trouble and require early maintenance. If the void content is too high, water can soak into the surface. When the water freezes, the pavement will ravel*. Air also can get in, causing the asphalt to harden and become brittle. The Inspector must make sure that all parts of the pavement, including joints, edges, and areas next to structures, are compacted to a high density by thorough rolling while the temperature is high enough.

Rolling of the binder course or wearing course must start as soon as possible after the material is spread by the paver. This first rolling is usually called breakdown rolling. It is absolutely necessary that the rolling be done while the material is at the proper temperature. The right time usually is directly after spreading.

It is good practice to do the first or breakdown rolling with a three-wheel roller operating with its drive wheels toward the spreader. With this arrangement the loose mixture is "tucked under" the power-driven rear wheels instead of being pushed ahead by the front roll. However, on steep grades it may be necessary to turn the roller so the front roller is toward the spreader to prevent the drive wheels of the roller from "chattering". The breakdown roller should work as close to the spreader as possible, covering all of the lane once while the mix is still hot. After the surface is rolled, it may show small hair-line cracks at right angles to the centerline. These cracks may result from rolling the mix while it is too hot, but they may also be caused by too much fine material (dust or filler) in the mix. The mix should be checked to make sure that it does not contain too much material which passes the No. 200 sieve. If it does, the mix should be changed at the plant so it can be rolled while hot enough to get good compaction.

When heavy, self-propelled rubber-tired rollers are used, they should be so ballasted and the tire pressure so adjusted that they can operate on the hot pavement directly behind the breakdown roller. The tires should mark the hot pavement slightly. The marks show that kneading action and compaction are taking place. Used in this manner, rubber-tired rollers close hair cracks and reduce the voids in the pavement to a low volume. Sometimes, these rollers cause asphalt to flush to the surface. This flushing is not a sign of improper rolling, but does show that the mix contains too much asphalt. If such a mix was not rolled with rubber-tired rollers, the action of traffic would, in time, cause asphalt to flush to the surface of the wearing course, which would then become unstable.

The chief problem with rubber-tired rollers is that the hot paving mixture sometimes sticks to the tires and is picked up. This pick-up is often used as an excuse for not rolling the pavement while it is hot enough for the rolling to do the most good. However, pick-up is not a serious matter if the rollers are operated properly. The tires must have no tack coat or other asphalt on them. They can be cleaned by washing with a solvent, such as fuel oil or kerosene. Before being used on hot pavement, the roller should be operated on warm pavement with very little water on the wheels so that the tires will warm up. During rolling, as little water as possible should be used and the water must be distributed uniformly over all tire surfaces. When its use is permitted, adding a liquid household detergent or a soluble oil to the water applied to the wheels helps to prevent pick-up.

Tandem rollers* and three-axle tandem rollers* produce the best results as finishing rollers. The finish rolling should not be started until the pavement surface has cooled to the temperature at which the rollers remove the marks left by the other rollers and leave a smooth finished surface. When at the right temperature, the surface does not feel uncomfortably hot to the hand.

Special care must be taken to compact each edge of a binder course or wearing course along its entire length. Before the lane is rolled, the material along the edges must be raised slightly above the surface in the rest of the lane with a tamping tool or lute, so that the full weight of the roller wheel will bear on the material at the outside of the mat. There will be little or no slumping at the edge under the roller wheels if the wheels extend no more than 6 inches beyond the edge during compaction.

Construction at Structures

64. Next to flush curbs, gutters, and structures, the surface course must have extra thickness so that the surface of the compacted mixture will be slightly above the top of the structure where the pavement butts up against it.

When a wearing course is placed next to a curb so as to form a bituminous concrete gutter, its surface must be sealed with hot asphalt cement of Class BM-1 or Class A-1 for a distance of 12 inches from the curb. The seal must be applied evenly to the surface by means of hot irons or squeegees so that the surface voids are completely filled but no surplus asphalt remains on the surface. Sealed joints at curbs are very important if the pavement is to be waterproofed; unless the surface is sealed at the joints, water will get in and freeze and the pavement may start to ravel and fail. Where the grade is slight, gutters should be tested with a straightedge and running water, to make sure that they drain to the outlet.

Constructing Longitudinal Joints

65. Particular attention must be given to longitudinal and transverse joints in both binder courses and wearing courses. If a joint is not properly formed and the material near it is not tightly compacted, the joint becomes one of the weakest places in the pavement.

The right way to make a longitudinal joint between a compacted lane and a new lane is described in the Specifications. First, any coarse material left on the surface of the compacted lane is swept onto the new lane. Then the Contractor should have any remaining fine material pushed into a small continuous pile, or windrow, which is just off the edge of the compacted lane and directly over the joint. When the joint is rolled, this extra material helps to make a tight joint. If it is left on the compacted lane, the fine material has no place to go and is rolled into a thin layer on the surface that usually scabs off quickly. After a little experience the Inspector can tell, by probing with a knife or an ice pick in the joint area, whether or not a tight joint is being obtained.

When a cold joint must be made, or when a joint must be made in cold weather, a joint heater helps to get a good joint. The heater must be approved by the Laboratory and must be used as directed. Infrared joint heaters are usually

used. The heater must be adjusted so that it will warm and soften the asphaltic concrete on the face of the joint without overheating and hardening the asphalt. No direct flame should touch the asphaltic concrete, and the surface temperature should not exceed 350 degrees F.

Constructing Transverse Joints

66. When a transverse joint is made as described in the Specifications, a strip of building or roofing paper may be put down where the lane will end. This paper makes it easier to remove the compacted material rounded off at the end of the lane, where the roller gets off and on. The end of the compacted part of the lane where the joint will be made must always have a firm, compacted edge that is nearly vertical and must have the proper grade and cross section. If the lane is constructed a short distance beyond the position of the joint (this is normally the case),it must be cut back to the joint. After a tack coat is applied to the edge, as required by the Specifications, the material for continuing the lane can be placed. The spreader must be backed up until the leading edge of the screed is behind the joint. The screed must be supported on the compacted material by wood or metal strips longer than the width of the screed and usually have a thickness equal to about one-fourth of the depth of the compacted course. The screw box of the paver should be filled to the normal height with hot material; then the paver should be run forward about 25 feet and stopped until the material at the joint has been compacted and the surface checked.

The joint must be properly "set-up"* by experienced finishers and the material near it compacted. When there is room enough for the roller to operate across the road, the material at the joint should first be rolled transversely. The roller should be on compacted material with the roller wheel overlapping the uncompacted material about 4 inches. Initial rolling across the joint (parallel to the pavement centerline) should be done with a tandem roller operating at its slowest speed. In its first pass, the roller should go about 3 or 4 feet onto the uncompacted material and return in the same path. Repeated passes for the same distance should overlap one-half the width of the roller. Immediately after this rolling, the joint must be checked with a straightedge. After the first pass of the roller across the joint onto the fresh material, the newly-compacted material near the joint should be about 1/16 to 1/8 inch higher than the previously compacted part of the lane. If straightedging shows that the joint is not satisfactory, the freshly compacted material must be removed and replaced with hot material from the hopper of the paver; this new material is placed and spread to proper grade and cross section by hand. The paver must not move on until the joint has been finished satisfactorily.

When a transverse joint is made against an existing pavement or bridge deck, a test should be made with a stringline to be sure that there is not a sharp change of grade at the joint; a sharp change would cause a bump. Three wood blocks of equal height are needed for the test. One block is put on the existing pavement about 15 feet from the joint. Another is put on the new pavement the same distance away from the joint. A stringline is stretched tightly between the two blocks. Then the third block is moved along under the line to detect any change of grade near the joint. If there is a noticeable break in

the grade, the grade of the new pavement should be corrected while the mix is still hot. To make the correction, the freshly rolled, but still hot, mix must be loosened with rakes or the toothed sides of lutes and material must be removed or added to get a good grade.

Testing Surface of Pavement

67. Every pavement course must be checked as required by, and in the manner described in, the Specifications. Surface defects which lower the riding quality of a pavement are short choppy waves, long waves, and changes in slope across the pavement.

Short choppy waves may be produced because the tracks on the paver were out of adjustment, the paver was operated too fast, or the brakes on trucks were set too tight. When a wearing course is laid by a paver in proper adjustment, the paver will take out short waves that may have been left in the binder course, but they may show up later on the surface of the pavement. Before a wearing course is laid, the binder course should be straightedged carefully, if short waves are found, the paver should be properly adjusted by the Contractor before it is used on the surface course. When using a straightedge the Inspector should always look at the pavement from the side of the straightedge opposite to the sun in order to be able to see low spots better.

Long waves may be caused by incorrect setting of the grade line to which the binder course was laid; too many changes in the setting or the paver speed. When a car travels at high speed, these changes from plan grade cause an uncomfortable motion of the car. Where there is a long wave, the distance between its end points is too great for it to be found with a straightedge. Such a wave is also too long to be corrected by normal action of the paver. The surface of the binder course should be checked by stringlining and corrected, if necessary, before the surface course is placed. The Inspector should not be concerned with the patch-like appearance of a binder course. Such an appearance is absolutely necessary when waves have been removed and this surface will not be seen after the wearing course is placed. If the binder course is laid properly, no corrections should be necessary in the wearing course.

Stringlining requires the use of three wood blocks of equal height (about 2 inches). Two of the blocks are placed about 50 feet apart and a strong, light line is stretched across them. A man at each end of the line stretches the line across the top of the block and under the sole of his shoe. By pulling on the line and then holding it against the pavement with the shoe, the line can be stretched very tight. The Inspector can then slide the third block along the line to detect changes in grade. After a length of pavement has been checked, the line and blocks should be moved ahead about half the length of the line, and the checking continued.

Changes in slope across the pavement give an uncomfortable rocking motion to a car traveling at high speed. These changes may be caused by improper operation of the control screws at one end of the paver screed. A straightedge with a carpenter's level attached to the center is needed to check the transverse grade. The level is fastened along the top of the straightedge so that the bubble is in the center of its tube when the straightedge is laid on a pavement with the correct transverse slope. If large changes in transverse slope are found in the binder course, the screed operator's ability to hold a

true grade should be checked. It may be necessary to use two grade lines, one on each side of the screed, to correct the trouble.

Shoulders

68. Shoulder material must not be placed against the edge of a binder course or wearing course until the rolling of the wearing course has been completed. If shoulders are built too soon, rollers and traffic will carry dirt from the shoulders onto the new pavement and prevent bond between the courses. The roller wheel may also be raised up at points where the shoulder material is slightly high, and fail to compact the pavement edges thoroughly at these points. However, care must be taken to prevent a breakdown of the pavement edges. Should edge breakdowns occur, they must be repaired immediately by the Contractor.

When the rolling of the wearing course has been completed and the edge has been thoroughly compacted, shoulder material should immediately be placed against the edge and rolled to form a temporary shoulder. The temporary shoulder should be wide enough to protect the edge and make the job safe for traffic.

Tests for Pavement Density

69. When tests for compaction (density) are specified or required by Special Provisions of the Proposal, the samples for the tests must be taken carefully from the finished pavement and handled in a way that will prevent any changes in shape. The samples must not be compacted at the edges during cutting, or bent when they are being removed from the pavement, handled and hauled to the Laboratory.

The samples are to be taken as directed. In the absence of definite instructions it is good practice to put a piece of 20-pound roofing felt 18 inches square on the underlying course at the point where the sample is to be taken. The felt may be held in place by the tack coat material or with roofing nails. The location of the felt should be referenced to marks on nearby pavement or to stakes driven in the shoulder.

After final rolling is completed and the pavement has cooled, a sample having a total surface area about 12 inches square should be cut from the pavement with a concrete saw. This is most easily done by first making two saw cuts 12 inches apart; then across and at right angles to these marks, several saw cuts are made to form pieces 3 inches wide and 6 inches long, or as directed. Other cuts should be made about 1 inch outside each edge of the sample to provide a strip 1-inch wide which can be pried and broken out and thrown away. The removal of this strip leaves working room to gently rock and loosen the sample pieces so that they can be taken out. The samples should be stored and moved with the side which was the top surface of the pavement placed against a smooth surface. They should be kept covered from the sun and as cool as possible until tested. The sample hole should be cut out to a size that will include all the saw marks. The contact surfaces should then be tacked; the hole filled with hot mixture; the mixture set up with a lute to the right height; and the course rolled with the specified roller.

Protection of Surface Courses

70. No traffic or loads are to be permitted on a newly completed surface course until the material has cooled to the point where it will not show wheel marks or be damaged. The Contractor must protect the pavement as provided in the Specifications.

CHAPTER VIII

BITUMINOUS CONCRETE

CHECK LIST OF IMPORTANT ITEMS

Have all items of plant equipment been checked for compliance with Department requirements? Is all required testing equipment on hand and in good condition? Are proper tools on hand for obtaining truly representative samples of asphalt, aggregate and completed mix? Are thermometers, that have been checked for accuracy, on hand for measuring temperatures of all materials and completed mixtures?

Has a positive check been make to make sure that the percent of asphalt used is proper for the gradation and filler content of the aggregate in the actual mix?

Are aggregates being checked constantly to make sure that they meet Specification requirements at all times at the point where they are fed to the drier?

Is cold feed being checked constantly to make sure that the aggregates are fed to the drier uniformly at all times?

Is aggregate discharged from the drier checked frequently, particularly at start-up, for temperature and completeness of drying?

Are all materials scales being checked constantly for accuracy and sensitivity?

Has Pugmill been checked for proper paddle arrangement (around the box), paddle wear, and capacity?

Are samples of all materials and the completed mixture being taken in such a way that they are truly representative and the results of tests have real meaning?

Are frequent checks being made to find if screening efficiency is within Specification limits at all times? If not, is the producer taking steps to permanently correct this condition?

Has surface on which hot-mix is to be laid been checked to make sure it is in proper condition? Has tack or prime coat been uniformly applied so that the specified coverage has been obtained?

Is temperature of mix being checked constantly before being dumped into hopper of paver-finisher?

Is paver-finisher in such condition and adjustment, and operated at a low enough speed to lay the paving material continuously, with an even texture from edge to edge of the paving lane? Is line being followed so that edge of lane is parallel to centerline at all times?

Are all transverse joints being completed to straightedge tolerances before paving is continued?

Is transverse grade of lane being checked constantly? Is straightedge in constant use to check smoothness of unrolled and rolled mat?

Are checks being made constantly to make sure that there is no unexpected underrun or overrun of material so that the number of square yards per ton being laid is within allowable limits?

Is all material being rolled with a uniform rolling pattern at a temperature high enough so that a dense and durable pavement is obtained?

Is the construction of longitudinal joint being constantly checked to make sure that a dense and watertight joint will result?

Is finished pavement being constantly checked by stringlining and straightedging and necessary corrective action taken to make sure that the smoothest possible riding surface is being obtained?

Have all necessary precautions been taken to protect newly laid pavement from damage by traffic?

CHAPTER IX

CONCRETE AND STEEL STRUCTURES

CONTENTS

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CHAPTER IX

CONCRETE AND STEEL STRUCTURES

Types of Structures

1. This Chapter deals with the inspection of various types of structures of concrete and steel. Among the structures of ordinary plain concrete* or reinforced concrete* are retaining walls,* culverts,* and various parts of bridges.* Bridge parts of prestressed concrete* and steel are also included.

The duties of the Inspector on concrete construction are almost the same for all types of structures. In most cases, only general methods will be given in this Manual. However, important special methods will also be referred to. In connection with concrete construction, the steel reinforcement* must be inspected carefully.

Important Dimensions of Bridges and Culverts

2. Each abutment* and pier* of a bridge should have the position and dimensions shown on the Drawings. Important dimensions of a pier are its length and width and the vertical distance from the top of its footing* to the surface on which the bridge superstructure* is supported. The length, width, and height of the main part of an abutment are also important dimensions. In addition, each wing wall* must have the direction and dimensions shown on the Drawings. Where a bridge is over a railroad, the required horizontal and vertical clearances* must be provided.

A culvert serves the same purpose as a bridge. A structure is called a bridge if the span is greater than 8 feet, and it is called a culvert if the span is less. When a structure has more than one opening, the sum of the spans of the openings will be taken as the span of the structure.

General Duties of Inspector-In-Charge

3. If the Contractor is required to take photographs at the site of the new structure, the District Engineer or his representative chooses the points from which the pictures are to be taken. However, the Inspector-in-Charge must make sure that the required pictures are taken before the site has been disturbed, during the progress of the work, and after the structure has been completed.

Before work on a bridge or other structure is started, stakes* showing the positions of important points will be set by a survey corps, and the Inspector-in-Charge should caution the Contractor not to move or disturb these stakes. The Contractor should use at least three guard stakes* at each marked point, or should protect the main stakes in some other way. At least two bench marks* will be established by the survey corps near the structure so that elevations of points on the structure can be checked easily.

NOTE: Words marked with an (*) are explained in the word list at the back of this book.

The Contractor and the Inspector-in-Charge will be given the information they need for building the structure according to the Drawings. Before any work except Clearing and Grubbing is started, the Inspector-in-Charge must make sure that he has all the necessary information. No corrections or changes in the Drawings for a bridge may be made in the field without the consent of the District Bridge Engineer or his authorized representative.

Before any excavation is started for a structure, a complete survey must be made to determine the elevation of the original ground around it. If such a survey has not been made previously, the Project Engineer should have one made. Elevations must also be taken after excavation has been completed, to determine the exact amount and class of the excavation. These elevations must be taken before any concrete or other masonry is placed, even though they may or may not be used as a basis for computing the final pay quantities.

For the purpose of computing correct final quantities, the Inspector-in-Charge must see to it that sketches showing every important dimension and elevation are made as the work progresses. Correct payment for work done by the Contractor cannot be made unless correct quantities are determined. When authorized changes are made in the Drawings, sketches must show the new details. The reasons for and the authority for them should also be given with such sketches.

Special care must be taken when making sketches for a bridge. All measurements must be made carefully and recorded in a special book or on a special form.

The Inspector-in-Charge computes quantities for monthly estimates, and then sends all measurements, sketches, and computations to the District Engineer to be checked and used for final quantities.

Lumber for Forms for Concrete

4. Because concrete is in a plastic condition when first placed in a structure, forms of some kind must be used to give it shape. Forms for highway structures are usually of wood. They are designed by the Contractor, who is responsible for the quality of the finished work, but they must meet certain requirements of the Specifications.* On a large structure or one with difficult formwork, the Contractor is required to submit form plans to the District Engineer for approval before work begins. Construction of the forms for such a structure should not be started until the plans have been approved.

Wooden forms are made at the job site. For a large structure, they may be built in a central shop and hauled to the site. They may be made of finished or unfinished lumber or of plywood.* The parts are held together by metal form ties* and other approved devices.

Forms must be set to the correct lines and grades, and their supports must be strong enough to hold them in position when the concrete in them is vibrated. They must also be tight enough to prevent loss of mortar.* They should give the concrete the right surface texture, and be easily removable from the hardened concrete. Forms should be built by experienced workmen.

Form material for surfaces that will be seen may be tongue-and-groove* or shiplap* dressed sheathing,* or plywood, or metal that meets Specification requirements. Rough lumber may be used for surfaces that will not be seen. In some cases, concrete may be placed in direct contact with the ground.

The Inspector should make certain that form lumber is not too dry, since it will then swell, bulge, or warp when soaked by water or by the water from freshly placed concrete. Also, the lumber should not be so green* that it will shrink and leave open joints, which will let mortar escape and will spoil the appearance of the finished concrete. Partly seasoned* lumber is best; kiln-dried* lumber is not suitable.

If forms that have been removed are to be used again, the Inspector should make sure that they are thoroughly clean and suitable for use. Sides and ends should be re-cut, if necessary, to give tight joints.

Supports and Bracing for Forms

5. All forms must be supported so that they will not sag and must be well braced so that they will not get out of line. Any falsework* or centering* must rest on a firm foundation. Special care must be taken when the ground is muddy or frozen.

Forms for the face of a wall usually consist of sheathing which is held in position by studs* and walers* (or wales*). Forms for beams* and other horizontal members above the ground are supported by vertical posts, which may or may not have short horizontal caps on top of them. The centering for an arch consists of a suitable framework. Each post in falsework or centering is usually set on a piece of plank called a mudsill. The area of the ground covered by the mudsill must be large enough to prevent the post from settling. Forms are braced in various ways; the best method for a particular part of a structure depends on the location and size of the part.

No matter how well the falsework or centering for a long-span concrete bridge may be constructed, the forms will sag when the fresh concrete is placed. In the case of an arch bridge, there will be still more sag when the centering is removed after the concrete has hardened. Therefore, the forms are set a little above the final desired elevations, or are given a camber.*

The centering of an arch should be supported in such a way that it can be lowered gradually when it is to be removed.

The hardened concrete will then sag slowly and will not be weakened by being strained suddenly. The centering may be supported on strike wedges,* sand boxes,* or jacks.*

Ties and Spacers for Walls

6. The forms for the two faces of a wall are held the proper distance apart by metal ties* and sometimes also by wooden spacer blocks or spreaders. Ties are of various types, and suitable devices are used to hold the ties in place. Metal ties are generally left in the hardened concrete, but each spreader must be removed after the concrete

reaches its level. If ties are to be removed after the concrete has hardened, they must be coated with grease or other approved material before the concrete is placed; and care must be taken to remove them without damaging the hardened concrete.

Preparing Forms to Receive Concrete

7. When concrete is placed in a right-angled corner of the forms, the concrete may not fill the forms completely or the sharp edge may be weak. To avoid such a defect, it is good practice to place a small V-shaped chamfer* strip in each corner of the forms.

Before concrete is placed, forms should be cleaned and thoroughly soaked with water. Where the concrete must have a good appearance, the inside surfaces of the forms should be coated with form oil or other approved material to prevent the forms from sticking to the concrete. Such coating material must not stain the concrete, and the use of tar paper is not permitted. In cold weather, forms should be cleaned and soaked with a steam jet or a stream of hot water. Also forms should be protected by covers, and heated if necessary, so that no concrete will be placed around ice or frost-coated reinforcement.*

Inspection of Forms

8. The Inspector must check each step in the construction of the forms. Before any concrete is placed, the alignment and grade of all forms must be checked, and the dimensions of each part of the structure should be measured and recorded for use in computing quantities of concrete. If no chamfer strips are shown on the Drawings and their use is desirable, the Inspector should bring the matter to the attention of the Assistant Construction Engineer. Also, in cold weather the Inspector should look closely at the bottoms of forms for narrow members, to make sure that no ice has formed there. If ice is found, it should be melted and the water removed.

At a bridge, the Inspector-in-Charge must check the location of each abutment and pier and the clearances at various points on the structure. He should make sure that the direction and dimensions of the wing walls of the abutments are as shown on the Drawings, so that the embankment material will not slide. When the structure is over a railroad, the horizontal and vertical clearances between the tracks and the bridge parts should be checked.

If the amount of camber* is not shown on the Drawings for a bridge, the Inspector-in-Charge should get the necessary information from the District Bridge Engineer. He should then make sure that proper allowance for camber is made in setting the forms.

Types of Steel Reinforcement

9. Plain concrete is strong in compression* but weak in tension.* Concrete reinforced with properly placed steel bars* or wire mesh* (welded wire fabric*) is widely used for almost all kinds of structures. In prestressed concrete* the reinforcement often consists of wires of high-strength steel.

Reinforcing bars, commonly called re-bars, are basically round in cross section, but their surfaces are deformed* to improve the bond* with the concrete. Square bars are no longer used, and the only round bars without deformed surfaces are 1/4-inch in diameter. The nominal diameter of a re-bar is given is given by a number, which indicates how many eighths of an inch are in the diameter. Thus, a No. 4 bar has a nominal diameter of 4/8 or 1/2-inch, and a No. 8 bar has a nominal diameter of 8/8 or 1-inch.

The common sizes of bars are those with whole numbers from 2 to 11. The weights of numbered steel reinforcing bars, in pounds per foot of length, are as follows:

Number	Weight per foot Pounds	Number	Weight per foot Pounds
2	.167	7	2.044
3	.376	8	2.670
4	.668	9	3.400
5	1.~~023~~ 1.043	10	4.303
6	1.502	11	5.313

Some re-bars are straight when placed in the structure, but others must be bent as shown on the Drawings.

Welded wire fabric used in structures generally consists of steel wires running in two directions at right angles to each other and welded together at their intersections. Fabrics with various sizes and spacings of bars are available.

Wires in prestressed concrete are usually arranged in strands.* The diameter of the strand is then used to describe the reinforcement.

Storage and Care of Reinforcement

10. Steel reinforcement should be stored so that it is protected from the weather. Before the steel is placed in the forms, it must be free from heavy rust coatings caused by out-of-door storage. A thin film of rust or mill scale that cannot be removed by rubbing with burlap does no harm, but any loose rust or scale must be removed by wire brushing. Other coatings on reinforcing steel, such as oil, grease, paint (except as otherwise provided in the Specifications), curing compound, mud, or weak dried mortar must also be cleaned off before concrete is placed around the steel.

Re-bars should be stored so that they can be easily found when needed. Identification tags should be left on groups of bars while they are in storage. Bars shipped with incorrect bends may be used if the corrections can be made without too much straightening and rebending. The Contractor should not be allowed to heat the bars in this process.

Position of Reinforcement

11. Each re-bar has its job to do, and the size and position of the bar shown on the Drawings have been determined carefully. Every bar

must be set in the forms in the right position and must be held in place so that it will not move while the concrete is being put in the forms. The position of the reinforcement is especially important in a thin slab. A reduction of 1 inch in the distance from the top of a 5-inch slab to the steel can reduce the safe load on the slab by about 25 percent.

Steel must not be too close to the forms. After the forms are stripped,* there must be enough concrete between the bars and the surface to keep the steel from slipping in the concrete and to prevent it from rusting. Rain water will penetrate a short distance into concrete and, if water reaches the steel, it will cause rusting. Rust takes up more space than the original steel. Formation of rust therefore builds up a pressure that may make pieces of concrete over the steel pop out. A spalled place thus produced looks bad and cannot be fixed easily. Also, rust will stain the surface of the concrete. When pieces of wire are used to fasten steel bars in place in the forms, the knots should be made on the side away from the form so that the ends of the wire will not cause rust spots.

When a reinforced concrete slab is built in forms, the steel should be held up by galvanized steel slab bolsters*, slab spacers*, or bar chairs* placed so that the steel will not deform under the weight of workmen walking on it or be pushed down when concrete is dropped on it. Where concrete is laid directly on earth or gravel, the steel should be supported on concrete blocks, made of the same concrete as that used in the slab. Steel chairs would be pushed down, and ordinary building bricks are so porous that they would lead water to the steel and cause rusting.

Splicing of Re-Bars

12. Re-bars should be spliced* only at points shown on the Drawings, unless a splice at some other point is approved by the Engineer. In every structure there are points where the tension* in the re-bars is greatest. If a splice is made at one of these points, a bar might pull loose and cause the structure to fail.

When re-bars are spliced at a point shown on the Drawings, or at a point approved by the Engineer, they should be fastened together tightly with at least three wire ties, and they must overlap at least 40 diameters. If No. 6 bars (3/4-inch in diameter) are spliced, each bar must extend at least 40 x 3/4, or 30, inches beyond the end of the other bar of the pair. This much lap is needed to get enough bond* between each bar and the concrete to keep the bar from pulling loose. Where bars are spliced, care must be taken to leave enough clear distance between each pair of lapped bars and the next pair. The clear distance to the form should also be great enough. Splices must be staggered* as far as possible, and as detailed on the Drawings.

Re-bars should not be welded at a splice, unless this operation has been directed by the Chief Bridge Engineer. If welding is permitted, it must be done by a welder who has been qualified by the Department.*

Inspection of Reinforcement

13. All inspection of reinforcing steel should not be put off until it has been set in the forms. The Inspector must examine steel reinforce-

ment when it arrives on the job, to be sure that it meets Specification requirements. While it is being set, he should check the size and positions of bars and the correctness of bends. Special attention should be given to the manner in which the steel is supported, and the clear distance to the forms should be measured. As bars are being wired together, the tightness of the wires should be tested. If ties become loose when the bars are shaken, they must be fixed so that the bars will not move when the concrete is compacted in the forms.

If welding of bars at a splice is allowed, the Inspector should see to it that each weld has the specified size and length and that the bars have not been burned or made smaller at the weld. A weld must never be cooled by throwing water on it.

Just before any concrete is placed, the Inspector should make sure that each bar is fastened securely in the forms in its correct position and that the steel is not coated with any material that would weaken the bond with the concrete.

If ends of reinforcing bars or dowels* are to be left exposed to the weather for more than two months, in order to permit an addition to the structure to be made at some later time, the Inspector should see to it that the exposed parts are protected by a coating of neat cement paste.*

The Inspector must prepare an itemized list of all steel reinforcement used in the structure. He should show how many bars of each size were put in and give any other important information about the bars.

If reinforcement is of any type other than steel bars, the inspection procedure is similar to that outlined for bars. Any special requirements of the Proposal or the Specifications should be noted.

Embedded Fixtures

14. The Inspector should make sure that all embedded fixtures, such as anchor bolts,* inserts,* pipe sleeves,* pipes, flashings,* and manhole-cover frames, called for on the Drawings are in their correct positions and are solidly fastened so that they cannot move when the concrete is placed and vibrated. If wood inserts are used, they must be soaked in water for at least 24 hours and until just before being put in the forms. The water in the concrete will make dry wood swell so that it cannot be easily gotten out of the hardened concrete and it may split the concrete.

Joints

15. Each expansion joint* must be in the right place and so constructed that it will do its job properly. The Inspector must see to it that joints are located as shown on the Drawings. Also, the joint must be straight and at right angles to the forms, and care must be taken to prevent concrete from bridging* the space left for expansion and contraction. Another very important duty of the Inspector is to make sure that sliding joints have been lubricated, if necessary, so that parts which should move will not be "frozen" in place when the concrete hardens.

Horizontal and vertical construction joints* shown on the Drawings, or called for by the Engineer must be inspected to be sure that they are made in accordance with Specification requirements. A poor construction joint is a place where water can get into the concrete and rust the steel or cause the concrete to spall.

A construction joint may often be necessary because of an unexpected delay in placing the concrete. Before such a joint is made, the Bridge Engineer should be asked to determine where it may be located. If the mixer breaks down, it may be necessary to mix concrete by hand in order that the work may be continued to a place where a construction joint can be placed.

A roughened concrete surface at a construction joint does not give enough bond, so dowel* bars and keyways* are normally required. The Inspector must see to it that the dimensions and positions of the keyway forms and dowel bars meet Specification requirements.

At a vertical joint on an exposed face, a chamfered* edge gives a better appearance, and prevents spalling of the concrete. Therefore, a beveled strip of wood is usually placed in the corner of the forms where the bulkhead* meets the face form. The Inspector should make sure that such chamfer strips are put in the forms wherever they are required by the Drawings or Specifications.

Sometimes, placing a straight joint would cause a feather-edge.* An example would be a continuous vertical joint between the main part of a bridge abutment and a wing wall with a sloping top. The joint should run vertically up to a point about 12 inches from the bottom of the coping* or the top of the wall. The upper part of the joint should then run at right angles to the slope of the coping or the top of the wall.

When a bridge deck* has a concrete wearing surface, expansion joints must always be placed in the wearing surface at the same locations as joints in the concrete deck slab, curbs, and wheel guards. The positions and types of expansion joints in parapets* are shown on the Drawings. However, if another joint is needed in a parapet, extra vertical re-bars must be placed in the parapet on each side of this joint to make up for the weakening of the parapet.

<u>Preparations for Placing Concrete</u>

16. Before any concrete is mixed or ordered for use in any part of a structure, the Inspector should make sure that the Contractor has everything ready. The Inspector should see to it that all provisions for drainage have been made, and that no water will be trapped after the structure is completed. Equipment must be on hand for placing concrete in every part of the structure without using long chutes, dropping the concrete more than 4 feet, or pushing it along the forms with a vibrator. The placement of the concrete must be planned ahead, so that concrete will be placed first in the corners of the forms and the top of the fresh concrete in the forms will be kept nearly level. Tools for spreading* the concrete must have handles long enough to reach all parts of the forms, and the vibrators* must be checked to see that they are in good condition. An extra vibrator must be on hand in case one breaks down.

Plans and preparations should be made, and equipment checked, to take care of possible stoppage of the work for such a cause as rain, a delay in mixing or delivery of concrete, or movement of the forms. Places where the use of a construction joint will be allowed should be located in advance, and material for bulkheads and keyways should be on hand. If concreting of a wall must be stopped before the forms are filled, straight wood strips should be nailed to the inside of the form to bring the top edge of the concrete to a neat line. Such strips should be cut in advance. Materials and equipment for curing* the concrete, and for protecting or heating it in cold weather, must be ready before placing of the concrete is started.

The Inspector should make sure that there will be enough workmen on the job at all times to permit the placing and finishing of the concrete to be carried on without stoppage until a suitable section of the structure is completed. A 30-minute break for lunch can cause a cold joint*. When concrete has stood long enough to take its initial set*, fresh concrete may not bond to the old surface. The "cold joint" where the old and fresh concrete meet will show as a crack on the surface after the forms are stripped* and may allow water to leak through it. Trouble can be prevented by properly installing a construction joint where work is stopped for some time.

Proportioning and Mixing Concrete

17. Detailed Specification requirements govern the quality of the materials used in concrete, and the proportioning* and mixing of the materials. Inspection of materials is covered in detail in Chapter XI. The concrete in a structure is designed to carry definite loads, and the strength of the whole structure depends on the vigilance of the Inspector in seeing to it that the concrete is proportioned, mixed, placed, cured, and finished as required by the Specifications. Concrete is not a fool-proof product, and proper attention must be given to all details in order to get a good job.

The aggregates* used in concrete must be sound and durable, well graded in size, and free from impurities.* To prevent segregation* of the materials in mixed concrete while the mixture is being handled, the right amounts of fine and coarse aggregates, cement, and water must be mixed thoroughly. The mixing time* with a machine must conform to the Specifications. Mixed concrete should not be allowed to remain in the mixer drum for more than 10 minutes after mixing is completed. The Specifications permit hand mixing in an emergency, but the volume of a batch mixed by hand should not be more than 1/2 cubic yard.

In order that plastic* concrete may be placed properly, it must have a certain degree of workability.* The amount of water added in mixing concrete should be just enough to permit the concrete to be placed with the equipment to be used for the structure. Too much water will cause concrete to be more porous, less durable, and weaker than it would be if the right amount of water were used. Concrete for a structure or portion of a structure which contains a large number of reinforcing bars must flow more easily than mass concrete.*

Precautions in Cold Weather

18. Concrete may be placed in cool and cold weather, but the Contractor must take proper precautions when mixing, placing, and curing the concrete to make sure that the completed structure will meet the requirements of the Specifications.

If concrete is to be placed in cool weather (when the air temperature is between 50 and 35 degress F.), the mixing water should be heated so that the temperature of the freshly mixed concrete will not be less than 50 degrees nor more than 80 degrees. The temperature of the mixing water must not exceed 150 degrees. If work is to be done in cold weather (when the air temperature is below 35 degress F.), both the mixing water and all aggregates must be heated to a temperature between 50 and 90 degrees, and the temperature of the mixed concrete should be between 50 and 80 degrees.

Calcium chloride* may be added to the concrete to make the cement set faster, if its use is approved by the Engineer.

Details of the requirements for cold-weather concreting are given in the Specifications. The purpose is to make sure that the freshly mixed concrete is warm enough to permit the hardening action to start. Once started, this action will give off more heat. As a result, the concrete will keep on hardening if it is kept moist and is not allowed to cool off too much. If the temperature of the concrete at the time of placing is too low, the hardening and warming actions may never get started, and the concrete may freeze or may never get its full strength.

Placing Concrete

19. Careful attention must be given to the method of moving the concrete from the mixer to the point of placing and the operation of placing it in the forms. Segregation* is the most common problem encountered in these phases of concrete construction, and its prevention is the reason for the detailed requirements of the Specifications in regard to moving and placing concrete.

The Specifications permit the Contractor to use a short chute* to lead concrete into the forms, provided that the chute is properly made and handled. A long chute can be used only with the approval of the Engineer. If the Contractor uses a chute, it must have a baffle* at the discharge end. When the concrete hits this baffle, it will drop straight down without segregating. If there is no baffle, the coarse aggregate will go to the far side of the form. So the concrete on the far side will not be uniform and may have gravel pockets or honeycomb.* Also, a chute must have a rounded metal bottom that is clean and smooth on the inside. It must have enough slope to allow the concrete to slide down it without the use of extra water. If the concrete that comes from the mixer will not slide in the chute, it must be pushed down the chute with shovels. EXTRA WATER SHOULD NEVER BE ADDED TO MIXED CONCRETE FOR THE PURPOSE OF MAKING IT RUN DOWN A CHUTE.

Concrete should never be dropped through the air for more than four feet. If it drops further, the coarse aggregate will separate out and the concrete will become segregated. As a result there will be too much mortar

in some places in the forms, and too much gravel or stone in other places. In a deep form some type of tremie* or elephant trunk* should be used to get the new concrete down to the surface of the concrete already in the forms.

In order to reduce segregation, the concrete must never be chuted or dumped into forms so that it hits the vertical reinforcing bars, except just above the bottom of the forms or just above the level of concrete already placed. Concrete must be placed around all reinforcement so as to embed the steel without having any honeycombed or porous concrete, and without moving the reinforcement out of position.

Spading Concrete

20. Air pockets or water pockets in fresh concrete leave holes in the hardened concrete. Fresh concrete must be spaded, vibrated, or tamped so that the air and free water can come to the surface.

If spades are used, the coarse aggregate must be pushed away from the surfaces of the forms. Spading the concrete along the forms helps to get rid of air bubbles that later will show up as shallow holes on the surface of the structure. When properly done, spading gives a smooth, dense, and pleasant-appearing surface which requires very little final surface rubbing.

Concrete should not be overworked during the spading operation. If the right amount of mixing water is used and the concrete is mixed, placed, and spaded properly, very little free water will come to the surface. If too much free water shows up on the surface of concrete, or bleeding* occurs, this water must be removed from the forms and steps taken to prevent further bleeding. If free water is allowed to remain on top of the concrete, a scum of thin soupy mortar, called laitance,* will collect on the upper surface. This laitance would be very weak if it were allowed to harden. So it should be removed from the forms.

When plywood forms are used, or when pressed-wood or metal liners are used with ordinary lumber, the forms often are so tight that it is hard for the air bubbles in the concrete to get out. When the forms are stripped, there may be small holes, sometimes called "bug-holes," in the surface of the concrete. Where very tight forms are used, extra care must be taken to place the concrete in shallow lifts,* to vibrate it thoroughly in order to release the air, and then to get the air out by sliding a spade down along the surface of the form and forcing its top away from the form.

Vibrating Concrete

21. Concrete in a structure is usually compacted by vibrators.* An internal vibrator, which has a spud at the end of a flexible shaft, should be used wherever possible. When the spud of a good vibrator is placed in the concrete, it makes the concrete more liquid so that entrapped air and water can come to the top. If the spud is left in one place too long, however, the coarse aggregate will sink through the mortar to the bottom of the layer and the concrete will segregate.

When the concrete hardens, the part of the layer with the most mortar in it will shrink more than the rest, and the concrete will crack. Cracks in the top of a beam, often located directly over the stirrups,* are usually a sign that the concrete has been vibrated too much.

The spud of the vibrator should never be left in one place for more than 5 seconds. As soon as air bubbles stop coming to the top, and the surface of the concrete around the spud or flexible shaft starts to look shiny, the spud should be pulled out, moved to a new position about 2 feet away, and dropped into the concrete there.

A good vibrator, running at the right speed, should change the appearance of the surface of the concrete for about 12 inches all around the spot at which the spud is placed in the concrete. If this result is not obtained, the vibrator is probably not getting all the air and extra water out of the concrete.

When the concrete is made more liquid with a good vibrator, it runs into all corners of the forms. As a result, the concrete will have a smooth surface when the forms are stripped. The vibrations also produce greater pressure on the forms, and form material must be thicker and stiffer than it would have to be if the concrete were spaded without using a vibrator. When a thin wall section is filled with stiff concrete and the concrete is vibrated with a powerful vibrator, the form pressure may be high enough to spread the forms because the tightening wedges at the ends of the form ties may be forced into the wood of the walers. On a high wall, the rate of placing of the concrete, measured in terms of rise of concrete per hour, should be controlled as directed by the Engineer.

Placing Concrete with Tremie

22. When a tremie* is used for placing concrete under water, it should meet the Specification requirements. A suitable method must be used to plug the opening at the bottom of the tremie while it is being lowered through the water and being filled with concrete.

The tremie must be kept filled with concrete during the placing operation, and its lower end must be kept submerged in fresh concrete. The concrete should be placed in shallow layers so that its surface remains roughly horizontal, and it should not be disturbed after it has been placed.

Inspection of Mixing and Placing

23. The Inspector should check the mixing operation frequently to make sure that the Specification requirements in regard to mixer size, mixing time, and drum speed are met. Mixed concrete should not be allowed to remain in the mixer drum too long after mixing has been completed. Uniformity in concrete is very important. Any batch of mixed concrete that does not have the right consistency* must be rejected. When hand mixing is permitted, the Inspector should take special care to see that the mixture meets the Specification requirements in regard to uniformity and consistency.

To make sure that segregation does not occur, the Inspector must check every step while concrete is being moved from the mixer to the forms and placed in the forms. If a batch of concrete contains so much water that the mortar* separates from the coarse aggregate while the concrete is being placed, the batch must be removed from the forms and thrown away before more concrete is mixed and placed. When vibrators* are used, the Inspector should check their size, type, and design to see that they conform to the Specification requirements. He should also make sure that enough extra vibrators are kept ready on the job, so that the work will not have to be stopped because a vibrator breaks down.

The Inspector must check the positions of the forms very often while the concrete is being placed to make sure that they stay in their right positions and do not sag or get out of alignment. While concrete is being placed for the deck of a bridge, the Inspector should take elevation readings at the center of the span. An even better method is to place telltales beneath the deck forms to provide a continuous check on settlement. If the deflection or settlement of the falsework is more than was allowed for, the Contractor should be directed to make necessary adjustments, so that all parts of the finished deck will have the elevations shown on the Drawings.

<u>Curing* of Concrete</u>

24. Concrete should not be disturbed any more than necessary after being placed. Overworking will cause segregation, or will weaken the bond* After concrete has been mixed and placed, it must be protected until it has hardened. It must be protected against the effects of freezing and early drying, as well as against vibrations and external loads. Concrete should not be exposed to the action of running water until it has hardened thoroughly. When the work is held up for any reason, the Contractor must use approved methods to protect freshly placed concrete against any kind of damage until work is started again.

After concrete has been placed, it must be covered as soon as possible and kept thoroughly wet for the entire curing period. In cold weather, all frost must be removed from the forms before any concrete is placed. The forms should be closed in, and enough heat should be furnished to keep the concrete from becoming chilled by cold forms and steel. Frequent thermometer readings of the temperature of the concrete mix and of the air inside the enclosed forms should be taken at all stages during placing and curing.

The final strength of the concrete and how long it will last depend a great deal on the curing. When concrete is freshly mixed and placed, the spaces between the grains of sand and particles of coarse aggregate are filled with cement paste.* If the concrete is kept warm and moist, hydration* of the cement takes place slowly, and the cement and water form a gel* which fills the spaces between the aggregate. After a time this gel hardens into a substance which binds the aggregate particles together and gives strength to the concrete. This action of gel formation and hardening starts off fast when the freshly mixed concrete is warm. The action of forming the gel also heats the concrete.

If the concrete is protected so that it does not get too cold or too hot (is at a temperature between about 50 and 80 degrees F.), the strength of the concrete will continue to increase for a long time, even for years, after it has been placed. The rate of increase will be rapid at first and then slower. The first few hours and days of curing are the most important. If the concrete is too cold when it is placed in the forms, the hydration of the cement will not be fast enough to keep the concrete warm. In cold weather, the concrete will not gain strength; and it may even freeze if it is not well protected.

If the concrete dries out, the hydration of the cement stops entirely. The action may not even start up again if the concrete is wetted again. In any case, concrete that has dried out soon after being placed will never be so good as concrete that was properly cured.

Unless concrete is fully cured, it not only will lack strength but will have other serious defects. If cement hydration is stopped too soon, some of the spaces between the aggregate particles will be left filled with water instead of hardened gel. When this water evaporates, holes like those in a sponge will be left in the hardened concrete. If the concrete gets wet in use, water will soak into these holes again and will dissolve some of the material in the cement. The water with this dissolved material in it will then tend to come to the surface of the concrete. When the water evaporates, the dissolved material sometimes appears as efflorescence* on the concrete or as "icicles" on the lower side of the slab. The action of the water in taking this material out weakens the concrete. Concrete which soaks up water is also damaged when the water freezes, and the water causes early rusting of any reinforcing steel that is too near the surface of the concrete.

<u>Methods of Curing</u>

25. Curing procedures in normal weather, cool weather, and cold weather are described in the Specifications.* Portection and curing according to the Specifications must be continued until the flexural strength as shown by test beams is not less than 500 pounds per square inch for Class AA concrete, Class A concrete, or high-early-strength (HES) concrete, and not less than 450 pounds per square inch for Class B concrete.

In normal weather, curing should begin as soon as the concrete is hard enough to support the burlap mats or other covering without damage. The covering must be kept in place and saturated for at least 7 days, or until the flexural strength required by the Specifications has been reached.

Concrete placed in the thinner sections of a structure, such as the tops of wing walls,* water tables,* wheel guards,* or parapets,* must be protected and cured carefully to prevent overheating, quick drying, or nonuniformity in the setting of the concrete for any other reason.

In cool weather, the Inspector should see that the Contractor follows the basic curing procedure for normal weather conditions. In addition, the Contractor has to place a layer of hay or straw at least 1 foot thick over concrete not covered by forms. Tarpaulins are then used as covers to prevent the hay or straw from being blown away.

10.00
6.30
1.20
2.45
14.95

In cold weather, the Specifications require the Contractor to enclose the concrete and forms in an approved type of housing, and to heat this housing. Heat can be furnished by salamanders* or by hot air or live steam in pipes. Live steam is best, since it avoids the drying effect of the other two methods. The Specifications also permit the use of blanket insulation.

Heated enclosures should provide enough space for the circulation of warm air. Canvas covers or other enclosing materials should not rest on corners or edges of the forms, because circulation of heat will be prevented and some parts of the concrete will be left at a low temperature. The housing should be tight and windproof.

Salamanders are convenient and cheap for small structures, but they produce dry heat. Also, they give off gases which may overcome people, and smoke from them often spoils the appearance of the concrete. Another objection to their use is that one may start a fire if they are placed too close to a tarpaulin or forms and are not watched carefully. When dry heat is furnished, the concrete must be kept supplied with enough moisture to prevent it from drying out too quickly.

When insulating blankets of balsam wood, cell-u-form, or similar material are used properly, enough heat is usually produced by the hydration process to keep the temperature of the concrete about constant during the early curing period. The blankets must be nailed tightly against the forms, and means must be provided for fastening their ends to studs and other parts of the forms.

When concrete has been heated during curing, the temperature should be lowered gradually at the end of the curing period. The heating equipment and the housing should never be removed rapidly from any portion of a structure immediately at the end of the curing period.

Concrete shrinks when it cools or dries out. If one part of a structure shrinks much more than another part near it, stresses are set up that will crack the concrete. When the concrete can cool down and dry out gradually, these stresses are distributed so that the concrete is less likely to be damaged.

Inspection of Curing

26. The Inspector must make sure that the curing method used by the Contractor is one described in the Specifications. In cold weather he must take frequent thermometer readings showing the temperature of the air inside the enclosure around the forms during placing and curing. All temperatures should be recorded in his diary. Temperature records should also be kept during the cooling-off period required by the Specifications.

If blanket insulation is used, the blankets should be inspected carefully to make sure that there are no tears in them. Torn blankets must be rejected or repaired so that they will be airproof and waterproof. In the event that proper control of curing is not being obtained, the Inspector should notify the Assistant Construction Engineer or the Bridge Engineer.

Removal of Forms

27. The Specifications set up specific time limitations for the removal of forms from the various parts of a structure. The Inspector must see that these requirements are met, since removal of the forms before the concrete has had time to harden and become strong enough may result in sudden or later failure of the structure or some of its parts.

The Inspector must also check the method of removing the forms to be sure that the concrete is not weakened or damaged in any other way. Special care should be used in removing arch forms or forms for the bottoms of beams. These forms should be removed slowly and carefully, to prevent sudden unbalanced loads that could damage the concrete or weaken the bond and perhaps cause failure.

Holes or voids in the hardened concrete surface that appear when the forms are removed must be filled with cement mortar in accordance with Specification requirements. If the work has a serious defect, the Inspector should bring the condition to the attention of the Engineer, who will see to it that the defect is corrected.

Finishing Concrete

28. If a vertical concrete surface will not be visible*in the completed structure, the Specifications usually permit it to be finished by spading. A flat spade is pushed down between the plastic concrete and the forms so that the coarse aggregate is forced away from the forms and mortar* flows against the forms.

Where a concrete surface will be visible, it should be finished so that there will be no high or low places or other irregularities. What is called a "normal" finish is produced by spading the surface while it is being placed and then, after the forms are removed, rubbing the surface of the hardened concrete with a carborundum stone.* Workmen should rub only enough to get rid of fins* and surface roughness, and should not start to remove good concrete. This rubbing must be done as soon as possible after the forms are stripped. Before the surface of the concrete is rubbed, it should be wetted by throwing water on it with a brush. Only enough water should be used to work up a "lather" on the concrete surface when it is rubbed. After the rubbing has been stopped, the surface should be kept moist by light sprinkling with a brush until the regular curing of the concrete is started again. If the concrete is rubbed before the concrete has hardened too much, and if the lather is kept moist and properly cured, the lather will set up* and make a hard surface. Painting the surface of hardened concrete with grout* or cement paste* should not be permitted.

Holes left by the removal of form ties should be packed with a dry mortar having the same proportions of cement and sand as the mortar of the concrete. The mortar should be tamped into the holes and kept moist on the surface until the concrete is cured. If the cured mortar is darker than the rest of the concrete, a blend of white cement and regular cement should be used.

Bearing areas of concrete surfaces of substructures,* upon which column bases, truss and girder bearing shoes, and similar parts will be placed, must be finished carefully so that full and uniform bearing will be furnished at the right elevation. If an important bearing part of a structure is not supported in the proper position, other parts will be deflected or stressed too much.

The Inspector must make sure that all surfaces are finished in accordance with the Specifications.

Protecting Anchor-Bolt Holes

29. When anchor bolts* are required, the Drawings will show where holes for them are to be left in the concrete. The open bolt holes do not cause any trouble during warm weather, but the concrete may be damaged if they get filled with water and water freezes. If placing of the anchor bolts is to be delayed until cold weather arrives, the holes must be tightly sealed.

Backfill Near Structures

30. It is very important that the backfill next to a structure be suitable granular material and be fully compacted. A very common fault in highway construction is the "bump at the bridge" caused by settlement of the backfill behind the abutment. It is hard to prevent this bump, since the structure will settle very little, if any, and there will always be some settlement of the fill next to it unless a great deal of extra attention is given to compaction of the fill. The approach slab at the end of a bridge or culvert helps to prevent a bump. If the fill settles very much, however, there will still be a bump. When there is a bump, the construction will be criticized by everyone who drives over it. Also, the pavement at a bump requires constant maintenance, and the maintenance patches spoil the looks of the pavement.

The backfill next to a structure must be placed on a solid foundation. Before any material is placed, the Inspector should make sure that all loose material and trash have been removed from the foundation area. Pieces of reinforcing bar can be driven into the foundation for several feet to see if the ground is firm and whether any holes or trash may have been covered over during construction. Any mud or water should be removed by means of a clamshell bucket or pumped out, and subgrade material should be placed at the proper moisture content up to the level of the drains or weep holes and fully compacted.

It is hard for large compaction equipment to work close to an abutment or wing wall. Special attention must be given to the compaction of the backfill material next to the concrete. In order to compact the subgrade and backfill material close to concrete and in an angle at a wing wall, it is usually necessary to use air-powered tampers or frogs,* or small vibratory compactors. If there is any loose, uncompacted material next to concrete, traffic vibrations will cause material from the nearby fill to move into the spaces in the loose material, and the fill near the concrete will settle.

Any backfill material meeting the requirements of the Specifications* should be placed in thin lifts* of uniform thickness, and each lift should be fully compacted before more material is placed. The surface of each lift should be kept level.

The backfill material must be spread so that each lift is uniform. If the material is dumped in piles, all the material in each pile should be moved and spread out uniformly. After the material in a lift is brought to the proper moisture content, it must be fully compacted until there is no movement during compaction. Where rollers are used for compaction, rolling should continue until there is no movement under the roller. Some materials will "ring" under the roller wheels when fully compacted.

When backfill is being placed around or over an arch or a rigid-frame structure, the material must be placed at the same level on both sides of the structure to prevent unbalanced loading. Backfill around footings of structures should be placed as soon as the forms are removed, and the material above the tops of footings must be placed in the time allowed by the Specifications.

The Inspector must see to it that the Contractor meets all requirements of the Specifications in regard to the placing of backfill next to structures.

Stone Backfill in Back of Structures

31. Stone backfill should be used in back of a wall, abutment,* or foundation* wherever there are signs of water seepage. If the water cannot drain from such a place, a head* may be built up and the soil around the structure may become saturated. The stone should usually be placed against the back of the structure. Stone backfill should extend far enough behind the structure and be high enough to include all places at which water might seep into the fill. Shale should not be used for material in a stone backfill.

Records and Measurements for Bridges

32. When a bridge is being built, the Inspector must make accurate measurements and keep complete records as the work progresses. Before any concrete is placed in the forms, the length of each span* must be checked and recorded in the Inspector's field book. The span should be measured along the centerline of the structure and also along the centerlines of the bearings of the two outside beams, girders, or trusses. After the forms have been removed, but before any backfill is placed or any superstructure* steel is set, the span length must again be measured at the same locations. These lengths must be recorded in the Inspector's field book and compared with the previous measurements. Any differences must be brought immediately to the attention of the District Bridge Engineer.

Where a skew* bridge is built on a grade, special care must be taken to get the tops of abutments and piers at the right elevations. These elevations may be shown on the Drawings. If they are not, the required elevation of any corner can be found as follows: The first step is to compute the station of a point on the centerline of the bridge directly opposite the corner. The next step is to find the grade elevation at this point. From this elevation should be subtracted the thickness of the bridge floor, wearing surface, and plates, if there are any. The crown of the roadway and the depth of the supports must also be considered. When the bridge is built on a superelevated* curve, the superelevation must be considered. The elevations of the tops of abutments and piers will be computed by the District Bridge Engineer, but should be checked by the Inspector-in-Charge.

Construction of Bridge Deck

33. The superstructure concrete of a bridge is made up of the deck,* wheel guards,* and parapets.* Special attention must be given to each of these parts, since the traveling public judges a highway bridge by its appearance and by the riding qualities of the deck.

The riding-quality requirements for a bridge deck are the same as those for pavement. When a bridge is to have a concrete wearing surface, the practices used in constructing good concrete paving should be used to obtain a smooth riding deck. The deck should have a grade line without waves or dips, uniform surface texture, and a true cross section.

Rough riding on a bridge deck is usually caused by either of the following conditions:

1. Failure to adjust properly the elevations of screed guides and end dams* to compensate for actual beam camber and the deflection of beams due to the weight of the deck slab.

2. Poor methods for placing or finishing the concrete.

Before the start of construction, the District Bridge Engineer and the Inspector-in-Charge should discuss with the Contractor the plan of operation and agree on the type of screed rails and their support; the type of finishing equipment; the number and types of mixers and equipment for transporting the concrete; the procedures for placing, finishing, and curing the concrete; and the number of finishers and their experience and skill in this type of work.

Finishing Equipment

34. Unless there are special requirements, the type of finishing machine used for a bridge deck depends on the bridge length. It may be fully powered, very much like a machine used on a concrete pavement, and may require heavy rails as guides. Or it may be a vibrating screed or a heavy hand-operated screed, for which pipe-type guides are suitable. Hand-operated screeds should be used only for small areas where other

types cannot be guided properly. The rails for heavier finishing machines are usually set above the pavement surface to allow for hand finishing outside the screeded area. For hand screeding, temporary pipe guides are used. These guides are removed as soon as screeding is completed.

The screeding surfaces of all equipment should always be checked for proper cross section and straightness before concrete is placed. The screeds on finishing machines which ride on rails above the pavement surface should be checked in the down position to make sure that they are adjusted to the right profile grade and cross section.

The profile* of the finished deck depends on the setting of the screed guides or rails. The guides must be accurately set to the proper grade line. The elevations for the tops of deck forms and screed rails must be calculated. They will depend on the elevations of the tops of the supporting beams or girders after their erection, the deflections due to dead load (obtained from the Drawings), the desired elevations of the finished surface, and the depth of the deck slab. If all the necessary values are not given on the Drawings, the Bridge Engineer should be contacted before the screed rails are set.

The screed guides or rails should be located over stringers or main beams and should not be supported on deck forms. Rails must be held in place by fixed supports which are close enough together to permit the rails to carry the heavy finishing machine without bending. The supports must be adjustable for height and spaced closely enough to prevent bending of the rails, and the supports on one side of the roadway should be opposite the centers of the spaces on the other side. They should be of a type that can be removed easily after screeding is completed.

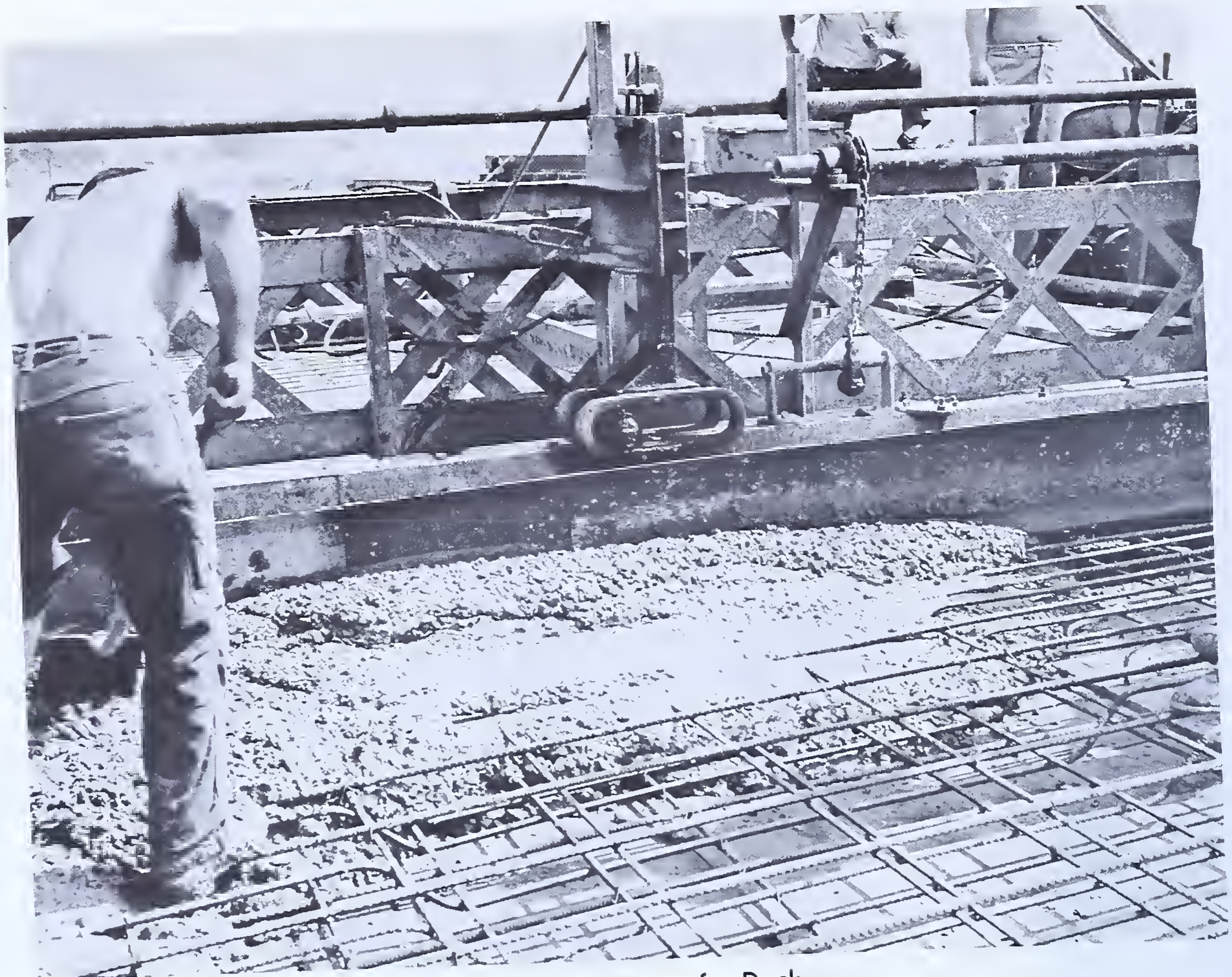
<u>Placing Concrete for Deck</u> **(See IX - 20B)**

35. Before the Contractor is allowed to place concrete for the deck, the Inspector should check the following items:

Elevations of screed guides or rails
Trueness of screeds and straightedges
Equipment for transporting the concrete
Number of finishers
Equipment for finishing and curing the concrete
Important dimensions
Spacing and cleanliness of reinforcing steel.

If the weather is windy and hot, the Contractor may decide to postpone the placing of the concrete, because the surface of the concrete will dry out fast and getting a good finish will be difficult. The Drawings for a bridge deck will often show a pouring pattern which requires construction joints. This pattern must be followed, since less stress will be placed on the concrete already placed and hardened when the beams are deflected by the weight of the new concrete. Because of the deflection of the beams, the first batch of concrete placed in a portion of the slab between construction joints must still be plastic when the last batch in that portion is placed. If concrete moves after it has set and while it is still weak, cracks will be "built" into the deck.

Prestressed Beams on Bridge Piers

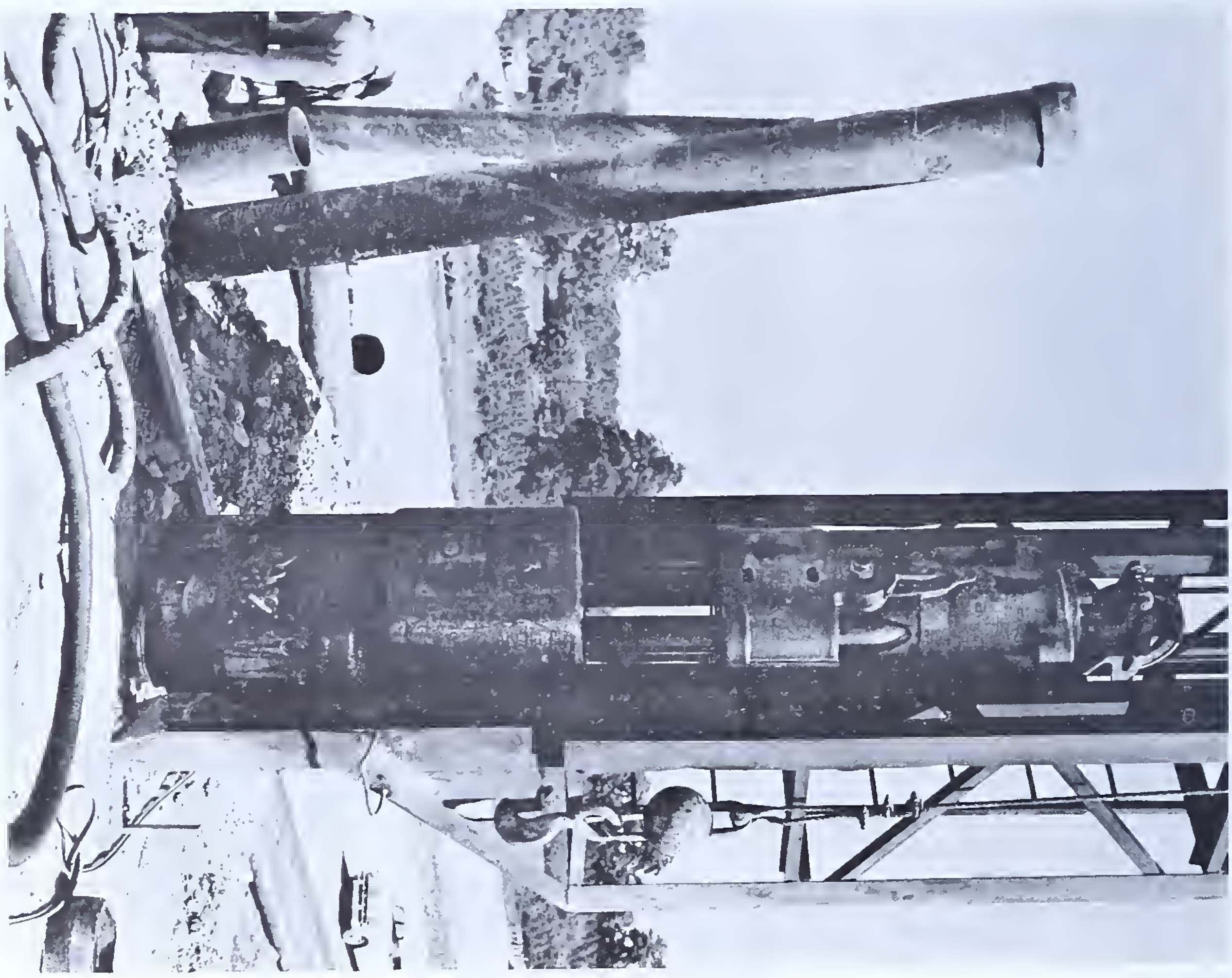


Placing Concrete for Deck

Vibrating Deck Concrete

Finishing Deck Concrete

Pile driver—Piles



Pile Driver hammer

The concrete delivered to the deck must be uniform in composition, workability, and consistency. It must be placed in the forms without segregation and as close as possible to its final position. It should be dumped into the forms from a crane bucket or hand buggies, to nearly uniform thickness. It should then be spread by workmen with shovels so as to leave a small amount to be struck off the surface by the finishing screed. Vibrators should be used to compact the concrete around the reinforcing steel and in the corners of the forms. Vibrating screeds will not do this work.

Finishing and Curing Deck Concrete **(See IX - 20C)**

36. Finishing machines or vibrating screeds pulled by winch and cable should be moved at a slow, uniform rate. The screed should always be carrying a uniform amount of concrete across its full width. It should not be used to bulldoze the concrete.

After screeding is completed, the screed guides and supports must be removed without disturbing the screeded concrete. Holes left after their removal must be filled with fresh concrete, and not with mortar or with concrete screeded off the surface.

A bridge deck is given its final finish in about the same way as concrete pavement, but there is less room for the finishers. The work should be done by finishers experienced in concrete pavement construction. The average finisher who usually works on building floors or sidewalks does not know how to get a good riding surface, and his work on a bridge deck should be checked often.

Finishing operations on a bridge deck should be held back as long as possible, so that the concrete will have had time to bleed* and shrink. When the concrete has started to set, it should be finished as quickly as possible without overworking the surface. The final surface finishing should be done with wooden scraping straightedges 10 feet long and having long handles. It is the Inspector's job to make sure that their bottom edges are straight and that they are used right. He should also see to it that after the surface has been finished with the scraping straightedges, it is checked with a light checking straightedge. Any high spots must be cut down with a scraping straightedge. Low spots must be filled with fresh concrete.

The finishers may want to use smoothing floats, which are usually 4 inches wide and about 4 feet long. Such floats may be used for small repairs, but should not be used for finishing the entire deck. The use of smoothing floats usually makes short waves or hollows in the surface. The surface must always be checked with the 10 foot straightedge after smoothing floats are used. The final texture is obtained with a burlap drag, which should be kept wet and free from hardened concrete.

When wet burlap is used for curing it should be placed on a bridge deck as soon as it can be laid without marring the surface. A double layer is required. The burlap must be kept saturated, so that the concrete will not crack during curing and will have its full strength. Close attention to curing of a bridge deck is necessary, because such a large area of concrete surface is exposed to the air.

Forms for Parapets

37. Besides judging a bridge by the riding qualities of the deck, the traveling public expects a neat appearance. The appearance of the parapets and wheel guards is criticized more than that of any other part of a bridge. The public will rate these parts on the straightness of their edges and on the uniformity of the finish and color of the concrete.

The appearance of the surfaces and edges of parapets and wheel guards depends on the quality of the carpenter work and of the material used in building the forms. The Inspector should make sure that all form lumber used is clean and has a finish which will give good results, and that forms are built to straight and neat lines. When checking forms, the Inspector should make use of surveyors' instruments, stringlines, rulers, and plumb bobs. As a final check, the edges of parapets, the edges of wheel guards, or "V" grooving, and other exposed edges and corners should be "eyed in," and minor adjustments should be made to get a smooth line.

Most Drawings will show that all outside corners are to be chamfered.* A chamfered corner is obtained by placing a V-shaped strip in the corner of the forms. Use of a square corner may result in a rough edge of weak mortar. The Drawings should be checked before form construction is started; if no chamfer strips are shown, this fact should be brought to the attention of the Bridge Engineer.

Placing and Finishing Concrete in Parapet

38. Parapet concrete is usually placed in two or three separate pours,* as shown on the Drawings. There may be one pour for the part of the parapet below the surface of the deck, a second pour for the wheel guard, and a third pour for the upper part of the parapet. Sometimes the wheel guard is poured with one of the other parts. The construction joints on the roadway side are hidden in the change from a horizontal surface to a vertical surface. On the outside it is intended that a construction joint be hidden in a "V" notch, the form for which becomes the grade strip for the top of the pour. Because sound concrete cannot be placed in a sharp corner, the appearance of the parapet surface will be spoiled if the "V" notches are omitted or the Contractor is allowed to finish a pour above or below a "V" notch.

The procedures described for other concrete should be used in placing and finishing the concrete in a parapet. Special attention should be given to the vibrating and spading operations, in order to produce a surface which is uniform in texture and free from large air voids. Vibrating alone will not get rid of the air bubbles in the upper part of a wall. The concrete in this part must be spaded.

If the forms for a parapet are built in a workmanlike manner and of good material, and if the concrete is properly placed, vibrated, and spaded, the surfaces should require little finishing when the forms are removed. Each exposed surface should be given a "normal" finish by spading the fresh concrete and rubbing the hardened surface with a carborundum stone as soon as possible after the forms are removed.

Back Walls and End Dam

39. After the deck of a bridge has been completed, the back wall* at the top of each abutment should be built. A bridge deck is usually supported on its abutments so that there is a "fixed" end and an expansion* end. At the fixed end, as the term implies, the deck cannot move in the direction of the span. At the expansion end, the deck can move back and forth in the direction of the span for a limited distance to allow for changes in the length of the deck as the temperature and loading vary.

At the fixed end, only a narrow space is left between the concrete of the deck and the back wall of the abutment, and this space is filled with expansion-joint material. The bearing is constructed so that movement of the deck is prevented. At the expansion end, a fairly wide space is left between the deck slab and the back wall, and the bearing is arranged so that the end of the deck slab can easily slide toward or away from the back wall. This space is covered by a steel end dam*. All parts of the end dam are to be assembled before any deck concrete is poured.

Care must be taken in placing the concrete under and around the end dam. The concrete must be vibrated carefully, and holes must be left in the horizontal leg of the end dam to permit entrapped air to get out.

On a bridge with a steel superstructure, the concrete back walls should not be built until after all superstructure steel and the concrete deck of the bridge have been placed. Other concrete parts of the abutment above the level of the bridge seat* also should be built at that time.

Handling Prestressed Concrete Beams

40. It is very important that a prestressed concrete beam be lifted at the ends by the hooks furnished by the manufacturer. Also, if it is necessary to store a beam of this type at the job-site, care should be taken by the Contractor to set the beam on skids placed as close to its ends as possible.

Most of the steel reinforcement in a prestressed concrete beam is in the bottom of the beam. If the lifting device is attached to a beam at the center, or if a beam is stored on a side or upside down, the steel will not be in a position to resist the tensile stresses caused by the weight of the beam. The concrete will then be cracked, and the beam may be badly damaged.

Approach-Slab Reinforcement

41. Additional steel reinforcement is used at the end of an approach slab which is supported on the back wall of an abutment. Details of this reinforcement are shown on Sheet B-1 of the Standard Drawings. It consists of a mat of No. 4 bars 20 feet long which is placed 2 inches from the bottom of the approach slab. This mat must be supported on the compacted fill by concrete blocks, so that it will not be pushed down when the concrete is placed in the slab.

Types of Foundations

42. A column usually rests on a footing,* which has a much larger area than the column. The footing spreads the column load over such an area of the ground that the settlement of the structure will not be too great. Column footings are generally of reinforced concrete.

Even though the bottom of a large retaining wall, bridge pier, or abutment may provide enough bearing area on the ground, such a structure usually has a footing which is somewhat larger than the bottom of the structure. The footing helps to prevent overturning of the structure by the horizontal forces acting on it.

Where the soil under a footing is very weak, piles* of timber, steel, or reinforced concrete may be driven into the ground to provide enough support for a footing of reasonable size. Concrete piles are often cast in place. Where a structure can be founded on rock or other firm material within 10 feet of footing elevation, foundation columns* are sometimes used instead of piles and footings.

Excavation for Footings

43. The Drawings generally show the approximate elevation of the bottom of each footing and the type of material expected to be found in the ground at that depth. The Inspector-in-Charge should caution the Contractor not to excavate below the elevation shown on the Drawings for the bottom of a footing. When the excavation for a footing has been completed to the depth shown, the District Construction Engineer, his representative, or the Bridge Engineer must inspect and approve the bottom of each footing excavation before any concrete is placed. If there is water in the excavation, it must be pumped out so that the ground can be inspected properly.

In case the material at the bottom of the excavation differs from that expected, the Drawings may have to be changed. The Assistant District Construction Engineer may need more information about the material at a lower elevation. Samples of the soil at various depths may then have to be taken for tests. A rock foundation is tested by drilling at least 5 feet below the bottom of the excavation to make sure that there are no mud seams which might allow the structure to settle.

If the material at the bottom of the original excavation is not good, and if it is found that satisfactory foundation material can be reached by going a few feet lower, the Contractor may be ordered in writing to excavate more material. He will receive extra pay for this excavation.

Where footing must be placed below the water level and cofferdams* are to be built to keep the excavation dry, the cofferdams must meet the Specification requirements.

The Inspector must measure and check the length, width, and depth of each footing excavation, and must record these dimensions in his notebook as soon as the excavation has been completed. A description of the type of material found in the excavation must also be recorded. Under normal conditions footing forms, concrete, and reinforcement must be inspected in the manner described for structures in general. Where large cofferdams are needed and footings are built within them, the Inspector-in-Charge should ask the Assistant Construction Engineer for instructions in regard to inspection.

Footings on Rock

44. When the bottom of a footing is to rest on rock, the surface of the rock may be made level, sloping, or stepped, as shown on the Drawings. Footings on sound rock are often keyed into the rock to a depth of 6 to 12 inches.

Any change from the lines shown on the Drawings must be approved by the Bridge Engineer. When drilling and blasting are necessary, the Inspector must see that the rock is removed in accordance with the Specifications, as nearly as possible to the required lines, and with as little disturbance as possible to the material that is left in place. If the Contractor removes rock below the elevations shown, specified, or directed, the quantity of extra excavation should be measured by the Inspector. The space left by excess excavation of rock must be filled with concrete. The volumes of excavation and concrete to be paid for are only the actual volumes for the elevations and other dimensions shown, specified, or directed.

Foundation Columns

45. A foundation column is a reinforced concrete column formed inside a steel shell which is drawn up as the concrete hardens. Such a column should rest on good rock or other firm material. The shell may be in sections. The bottom section of each shell is placed in a pit excavated below the surrounding ground.

The Inspector must make sure that the bottom of each shell is in the correct position and that the sections of the shell are aligned properly. Steel reinforcement of the required length must be set in the shell before any concrete is placed. The steel bars should extend above the top of the column at least to the height shown or specified for the lapping of bars.

Placing of the concrete, especially in the lower sections, must be constantly watched by the Inspector to be sure that each shell has the full diameter and that the shell is solidly filled with concrete. If the bottom of the excavation cannot be clearly seen through the shell, an electric light should be lowered until it rests on the bottom, and the light should be slowly pulled up so that the sides of the shell can be inspected. Another method of getting light inside the shell is to reflect sunlight with a small mirror. If there is any mud or water at the bottom of the shell, it must be bailed out before any concrete is placed. Any dents or bulges in the shell which make the inside diameter smaller must be repaired so that the column will have its full strength. The concrete must be placed and vibrated in accordance with the Specifications. Where foundation columns would be more than 10 feet long the Chief Bridge Engineer shall be notified.

Cast-in-Place Concrete Piles

46. A concrete pile may be cast in place by driving a steel shell or steel pipe, with a closed lower end, into the ground and filling it with concrete. Steel reinforcement must be provided where called for.

Before a steel shell or pipe is driven into the ground, the Inspector should make sure that it meets the Specification requirements relating to material, dimensions, method of joining sections, and other details. After a shell or pipe has been driven to its final position, and before any concrete is placed in it, the Inspector should lower a light attached to a cord to its bottom, or he should reflect sunlight into it with a small mirror. Any mud or water in the shell or pipe must be bailed out before concrete is put in. Also, any dents or bulges in the metal which would reduce the diameter of the concrete pile must be removed.

Timber Piles

47. Timber piles are to be inspected at the job site before they are driven. They must be checked for soundness, straightness, and minimum and maximum dimensions, as required by the Specifications.

The Inspector should make certain that all bark has been removed from the pile before it is driven. He should also check the pile tip and pile butt to see that they have been sawed off square (at right angles to the axis of the pile).

Where timber piles are to be driven into fairly hard ground, a metal point is usually fastened to the tip of each pile to protect it from damage. The Inspector should make sure that the metal point is of an approved type and is firmly attached to the pile.

Precast Reinforced Concrete Piles

48. Precast reinforced concrete piles are inspected while being made, handled, and driven. While being made, they are inspected by representatives of the Laboratory. Faulty casting or curing methods, or improper handling, will cause small cracks in a pile, and these cracks will open up later and result in damage to the pile.

As soon as the side and end forms have been removed from a pile, it should be marked with a serial number and the date of casting, in order that it may be identified later for driving and for a permanent record of its position in the structure. After the piles have been cured, they should be handled very carefully, while being moved and stored, in accordance with the Specifications. A fairly short pile (up to 25 feet long) should be picked up at the upper one-third point. A longer pile should be picked up at the points shown on the Drawings or as directed by the Engineer.

Steel Beam Piles

49. Piles often consist of H-shaped steel beams. The Inspector should see to it that all parts of such piles meet Specification requirements, and are of the type and size shown on the Drawings or specified in the contract. Each pile should be checked to make sure that it was not bent or damaged in any other way while being shipped or handled. If the Contractor intends to use piles with splices, he must have his proposed method of splicing approved by the District Bridge Engineer.

Pile-Driving Equipment **(See IX - 20D)**

50. Piles are driven with either a drop hammer* or a power hammer* operated by steam, diesel or compressed air. The hammer and leads* should be checked to see that they meet Specification requirements and are in good working condition. Performance of the equipment should be watched carefully while the first piles are being driven. To obtain good results, a power hammer must be operated under full pressure and must move through its full stroke. Sharp exhaust from a steam hammer indicates that there is enough pressure.

Nearly all manufacturers of power hammers base the required number of blows per minute on a mean effective pressure* (M.E.P.) of 80 psi in the hammer. If a hammer is supposed to strike 180 blows per minute, but is striking only 150 blows, the M.E.P. in the hammer is too low. A gage on a compressor, boiler, or feed line may not measure the true pressure in the hammer. This pressure may be much lower than the gage reading because valves, rings, bushings, or hoses are leaking badly. An air compressor used to operate a pile hammer must be able to furnish air at a rate at least 25 percent greater than that shown in the manufacturer's catalog for the hammer.

A pile driven into the ground can support a heavy load because of skin friction* between the pile and the soil around it. The bearing capacity of a pile, or the load the pile can carry, depends on the required number of blows of the hammer per inch of penetration.* Since the rate of penetration is affected by the number of blows per minute, the penetration should be measured when the hammer is striking the number of blows per minute specified in the manufacturer's catalog for it. When a hammer is in good working condition, it will strike this number of blows. If it is necessary to stop the driving operation for a time in order to get enough pressure for the required number of blows per minute, skin friction will be built up while the pile remains at rest. When driving is started again, allowance should be made during the initial blows for the fact that it will be necessary to break the pile loose.

Pile-driver leads should allow free movement of the hammer and yet should be rigid enough to hold the pile in correct alignment during driving.

Test Piles

51. Driving of test piles will be under the supervision of the District Bridge Engineer who will instruct the Inspector in regard to the driving of bearing piles. Test piles are usually driven to find out how long the permanent piles must be to support the structure without settlement. The Bridge Engineer will specify the exact points at which the test piles are to be driven, and will give the Contractor written instructions for driving them.

A test pile must be driven in one continuous operation. It is very important that detailed records be kept, showing the type and weight of the hammer used, the height of drop or the pressure in the hammer, the number of blows per minute, the type, length, and diameter of the pile, and number of blows per foot of penetration at various depths. Test piles are driven to refusal* or until the penetration per blow indicates that the specified bearing value has been attained.

Starting Bearing Piles

52. Bearing piles may be either plumb (vertical) or on a batter.* When a bearing pile is to be driven, its tip must be carefully placed in the correct position, and it must be vertical or at the correct batter. The first few blows of the hammer should be light. After the pile has been driven a few feet into the ground, all guy lines and braces should be tightened, and the alignment of the pile checked before the driving is continued. The alignment and location of each pile should be checked frequently while it is being driven. A template may be used by the Contractor as an aid in locating and aligning piles, but its use is not always required by the Specifications.

When a pile is to be driven on a batter, the leads should have the required batter, and the path of the hammer should have the same slope. The batter will be shown on the Drawings as the number of inches of horizontal distance in 12 inches of vertical distance.

The Inspector can check the batter of the leads by use of a triangle made of pieces of wood cut to the proper dimensions, nailed together, and plumbed with a carpenter's level.

Before the pile is lifted to the leads a tape should be stretched from the tip, and kiel*marks should be made at every foot of length of the pile. These marks are used to measure the penetration. At least every fifth mark should be numbered to show the distance from the tip.

Driving Bearing Piles

53. A bearing pile should be driven to refusal or until the penetration per blow is below the specified limit. Readings for penetration should be taken often and recorded so that the rate of penetration at various depths will be known. When a pile is being driven, a short piece of wood should be placed on the ground against the pile, and the number of blows required to drive each foot of the pile past the top edge of this piece should be recorded. If the driving is hard, or if the pile rebounds after a blow, marks 1 inch or 2 inches apart can be added between the foot marks, and the number of blows per inch can be recorded. When the penetration per blow becomes small enough, driving should be stopped, unless otherwise directed by the Assistant District Construction Engineer.

When a pile is being driven among boulders, or when driving is hard, the number of blows per inch must be watched for sudden changes, because the tips of the pile or a section of the pile near the tip may be shattered. If the pile is damaged, it will not have the expected bearing capacity. A broken pile should be pulled out and replaced.

Care must be taken to avoid overdriving* of a pile and resulting damage to it. A timber pile may be damaged not only by breaking, but also by brooming* at the head or the tip. Brooming makes the blows of the hammer less effective. A metal shoe on the tip helps to prevent brooming. A sudden increase in the rate of penetration may indicate a break below the surface.

Obstructions such as boulders and thin layers of hard material may cause binding or actual breaks in any pile. Continued driving against any unyielding obstacle may splinter a timber pile, shatter a concrete pile, flatten the point of a steel pile or bend it, or otherwise damage a pile. Local obstructions may be overcome by reducing the energy of the pile-driving equipment, until normal driving conditions can be resumed. In order to better understand unusual changes in penetration during driving of piles, special attention should be given to core boring data.

A pile should not be driven within 25 feet of a cast-in-place concrete pile until the concrete is fully cured, as cracking or failure of the uncured concrete may be caused by the vibration set up by the driving operation.

When a number of piles are driven close together into a softer layer below, the driving of the piles will sometimes build up pressure in the soft layer. If this pressure becomes high enough, driving more piles will cause some of the piles already driven to be lifted or pushed up. Piles that have been lifted have little or no bearing capacity, and serious settlement of a structure supported on such piles can occur. For this reason, a check should be made to compare the elevation of the top of each pile in a group just after it has

been driven, and the corresponding elevation when the driving of the whole group has been completed. The Specifications require that piles raised by the driving of nearby piles be re-driven until the proper penetration per blow is obtained.

Use of Water Jets

54. Water jets can and should be used in many locations as an aid in driving piles, particularly precast concrete piles. Either a single jet or a double jet may be used. It is usually easier to keep the pile on line with a double jet. Preboring or spudding must be used in fills where jetting may cause damage to the fill slopes.

The jet of water should be started as soon as the tip of the pile is set in position and before driving of the pile is begun. The jet pipe should be placed close to the pile and should be raised and lowered by lifting tackle as the soil is softened and washed away by the water, the pile will follow the jet down under the weight of the hammer or with the aid of light hammer taps. The jet should be raised from time to time, and the hammer used without the jet to determine the penetration per blow. When the proper elevation is nearly reached, the jet should be pulled out and the pile driven to solid bearing.

Cutting, Extending or Rebuilding Piles

55. If a pile has been driven and accepted, but its top is above the elevation shown on the Drawings, it may be cut off square with its axis. If the top of the pile has been damaged in driving, the Assistant District Construction Engineer may direct that it be cut off below the elevation shown on the Drawings.

A pile that is too short, or one that has been cut off low, may be extended or rebuilt, when such an operation is approved by the Assistant District Construction Engineer. The Inspector must make sure that the work is done in accordance with the Specifications. Careful inspection is particularly important in the case of a precast concrete pile. When the old concrete is being removed, care must be taken not to damage the reinforcing steel. The steel must be exposed, and the old and new bars must be lapped, also, the new concrete must be properly placed, cured, and finished.

Pile Record Sheet

56. The pile record sheet, Form 4188, should be on hand before pile driving begins. All necessary information about each pile should be put on this sheet as soon as the pile is driven and cut off. This form, completely filled out, must be attached to Form 442-A and the final quantity calculations. Form 442-A will not be approved until Form 4188 has been sent in and the recorded lengths of all piles have been checked.

Inspection of Material for Steel Structures

57. The erection of a steel structure is a process that requires careful and thorough inspection. Before the work is begun, the Inspector should familiarize himself with the shop and erection plans, the contract Drawings, the Specifications for Plain and Fabricated Steel Structures (Form 409), and any Special Provisions of the Contract that are important.

Each member in a shipment must be checked for correct dimensions as soon as the steel is received. The Inspector-in-Charge must keep a record of all shipments of steel, showing the car numbers, the date the shipment was received, the number of pieces of each kind, and the railroad-billed weights.

Whether or not the steel has been inspected at the shop, each piece of material must be checked in the field before it is placed in the structure, to make sure that it meets the requirements of the Drawings and Specifications. Faulty work must be corrected, or the piece must be rejected.

Steel members must be loaded, transported, unloaded, and stored in such a way that they will not be damaged and will be kept clean. The Inspector should make certain that the Contractor's workmen handle the steel carefully. Rolling a heavy member off a railroad car or truck may damage gusset plates, may distort outstanding legs of angles or beam flanges, or may bend an entire member.

The steel should be stored on skids or platforms, which are level and above the ground. It should be protected from water to avoid damage to shop paint or rusting of unpainted surfaces, and also from dirt, oil, and acid. The Contractor should store short heavy beams and columns upright, care being taken to insure safety. Long structural members, which must be laid flat, should be stored on supports placed fairly close together.

Anchor Bolts, Falsework, and Bearings

58. The Inspector must make sure that anchor bolts* are properly placed in the concrete foundations for a steel structure. Where falsework is required for the temporary support of a structure or part, it should be inspected carefully while it is being installed, and checked frequently as erection of the steel structure proceeds. The Contractor may be required to submit plans for the falsework and details of his intended erection procedure for approval by the Bridge Engineer.

Fixed parts of bearings for a steel bridge must be set accurately in the correct locations and at the elevations shown on the Drawings. Regardless of the temperature, a masonry plate* should always be set so that the anchor bolts are about at the centers of the holes in the plate. A usual requirement after all dead load is in place and the

falsework has been removed is as follows: at normal temperature, bearing rockers* or rollers* should be in a vertical position, and anchor bolts designed to stick up through the bearings at the expansion end should be at about the centers of the slotted holes.

The normal temperature upon which allowance for expansion or contraction of the steel superstructure of a bridge is based is 68 degrees F. If rockers or rollers are put in place at some other temperature the rockers must be tipped in such a direction or the rollers must be placed in such positions that proper allowance will be made for the expansion or contraction of the steel with change in temperature and also for the increase in length due to the deflection of the deck under full dead load. Allowance for deflection is especially important for a long span.

When 68 degrees F. is used as the temperature for the normal length of a span, the increase or decrease in the length for a temperature between 0 and 120 degrees F. should be obtained from the District Bridge Engineer. Corrections to span length, caused by dead load deflection should also be obtained from the District Bridge Engineer.

After a bridge has been erected, the Inspector should check the bearings to be sure that all the bearing parts make full contact. Wedging, shimming, and grouting may be necessary to get the required bearing.

Damaged or Defective Steel Members

59. Before a steel member of a bridge is placed, any deep bends in it must be straightened and other defects corrected. If the damage is serious, the condition must be brought to the attention of the District Bridge Engineer. Main members with bends, may be straightened by the fabricator under the direction of a qualified Welding Engineer and under the supervision of the District Bridge Engineer.

If the parts of a member are not assembled correctly, as when a stiffener or a cover plate is in the wrong place, the Inspector-in-Charge should ask the District Bridge Engineer what corrective measures can be taken.

Handling Steel Members

60. The Inspector must be certain that steel members, particularly those that are quite limber, are so handled during erection that they are not overstressed, bent or twisted, or otherwise damaged. Particular attention must be given to the way in which the Contractor picks up a long, built-up beam or girder to place it in the structure. The District Bridge Engineer should be asked for instructions in regard to the supervision of pick-up operations. The Inspector must also be certain that beams and girders are braced so as to prevent sidewise bending during erection. A plate girder must be held in a straight line until the floor system has been placed.

Assembly of Steel

61. During the erection of a steel bridge, the Inspector should make certain that all members are placed in the proper positions and that main supporting members are in correct vertical and horizontal alignment. The marks painted on the steel for identifying pieces should agree with those shown on the Drawings, and careful attention should be given to match marks at connections.

It is a good idea for the Inspector to recheck the relative positions of bearing connections in the substructure and superstructure just before the steel is put in place, so that no major changes will be necessary later. Before parts are assembled, bearing and other contact surfaces must be checked to see that they are clean and free from dirt, grease, or rust. Foreign material can be removed by wire-brushing or buffing the surfaces before the parts are joined.

Before riveting at a splice is begun, the parts are usually held together by drift pins* and temporary erection bolts. The Inspector must see to it that these temporary connections are made in accordance with Specification requirements, and that the parts to be spliced are held in their correct positions so that the rivets can be driven properly.

Drift pins of the proper size are usually installed first in a few sets of rivet holes to bring the parts into their proper relative positions and to keep the rivet holes in alignment until the rivets are driven.* Bolts of the specified size are put into other sets of holes and tightened to hold the piece in contact in order that the first few rivets may be tight. Then the drift pins and bolts are removed, and the riveting is completed.

Steel should fit together with little distortion or strain. A slight adjustment with drift pins is to be expected. But if the holes are too far out of place, the Contractor should not be allowed to force the parts into position with the drift pins. Improper use of drift pins may damage the material around the holes and will prestress the parts. Striking a part with a heavy sledge hammer to bring rivet holes into alignment should not be allowed either.

In most structures, a reasonable amount of reaming and drilling to match up holes is allowable. However, no reaming should be allowed in a splice in a tension chord of a truss, unless specific permission is obtained from the Chief Bridge Engineer.

Any errors which cannot be corrected by light drifting, a moderate amount of reaming and drilling, or slight chipping and cutting should be reported to the Chief Bridge Engineer. His approval of the proposed method of correcting the faults must be obtained before the method is used.

Checks and any necessary corrections should be made as the work progresses. Also, before permanent connections are made, the Inspector-in-Charge should make a final check to be sure that all members are aligned properly and set to give the required camber. This final checking should prevent any poor alignment from being built into the final structure.

Erection bolts should be drawn tight, preferably with impact wrenches, to prevent rivet metal from getting between surfaces that should be in contact. If the bolts are not tight enough, some of the rivets first driven will become loose as the riveting proceeds. As a result, a large number of rivets may have to be removed and replaced.

<u>Riveting Steel</u>

62. The Inspector must watch all riveting carefully, and should make sure that the rivets are of the right size and length; that they have full heads; that the heads are uniform in size and are centered on the shank; and that each rivet is driven tightly and with its head in contact with the connected parts.

Rivets should be heated uniformly to a light cherry red, and should fill the holes completely when driven. The Inspector should not allow the use of any rivets that are overheated, burned, or unevenly heated. He must not permit calking* or recupping of the heads. Overheating of a rivet is indicated by a glowing tip or by sparks flying when it is thrown. If a burned rivet is driven, it may be detected by the pitted surface on the head.

Rivets are tested when cold with a rivet-testing hammer, which has a cone-shaped or chisel-shaped peen. The Inspector should test each rivet in each connection for tightness by placing his finger or a metal washer alongside the rivet head and tapping the rivet head sidewise with the hammer. If he can feel any movement, the rivet is loose. The head of each loose rivet should be marked with the pointed peen of the hammer, and a circle should be drawn around the head with chalk. In case of doubt, a coin can be held loosely against one head of the rivet while the other head is tapped with the hammer. If the coin bounces, the rivet is loose. The Inspector should test rivets as soon as possible. A good procedure is for him to wait until all the rivets at one point have been driven, and to test them before the riveting crew moves the scaffold.

One way of removing a faulty rivet is to burn off or cut off one head (if this can be done without injury to the member) and then to punch out the rivet. If a head of a faulty rivet cannot be removed without injuring the member, the rivet must be drilled out.

The Inspector should keep a complete record of all field riveting, including defective rivets and their replacements.

Bolted Connections

63. Where shown on the Drawings, permanent connections may be made with high-strength bolts and nuts with hardened steel washers. Such bolts may be tightened to the tension required by the Specifications by use of a calibrated* power wrench driven by compressed air, or by the "turn of the nut" method.* The wrench must be calibrated daily by the Contractor for the same hose length that is used in installing the bolts in the structure.

Correction of Steel by Flame Cutting

64. Any flame cutting of structural steel must be done by a qualified welder. Before a workman is allowed to do any flame cutting, the Inspector-in-Charge should make sure that the man is capable of making a clean, fairly straight, smooth cut without burning or damaging adjacent metal. This requirement is very important, since a botched job of burning off a small piece of steel may overheat a large area of the steel next to it. As a result, the steel becomes hard and brittle and may crack or fail later on.

On alteration work, no flame cutting should be permitted unless the part to be cut is first relieved of all stress.

Qualifications of Welders

65. Only operators qualified by the Department should be permitted to do welding on work for the Department. The District Office will tell the Inspector-in-Charge whether or not a welder is qualified. If there is any doubt about the qualifications of a welder, the case should be referred to the Assistant District Construction Engineer.

Welders qualified by the Department have shown that they are able to make welds meeting the requirements of strength and workmanship.

It is the job of the Inspector to be sure that the operator always makes good welds. A welder who constantly makes undersized welds, or whose workmanship is poor, must be disqualified by the Inspector, and the disqualification reported to the Assistant District Construction Engineer.

Assembling Parts for Welding

66. When two pieces of steel are to be butt welded, the ends of the pieces must usually be beveled, and rough edges should be made smooth. Before any weld is made, the surfaces of the parts to be connected should be cleaned thoroughly for a distance of not less than 1 inch beyond the edges of the weld on all sides. However, a thin coat of clean, pure linseed oil need not be removed.

When the parts of a member are to be welded, they must be set in the proper positions and held in place securely in order to prevent harmful distortion or bending or twisting of the member. In some cases, distortion of a welded member may be corrected by cutting out all the welds, lining up the parts again, and making new welds. If there has been a permanent change in the shape of a part or in the alignment or length of the member, the member must be replaced.

Pieces to be welded together may be held securely in place by bolts, C-clamps, or other holding devices. A holding device must bring the parts to be welded in contact, and must prevent shifting of any piece. It must be placed so as not to interfere with the welder in making the weld. It must give him enough room to work and must let him see the weld at all times.

Appearance of Good and Poor Welds

67. A finished dependable weld of good workmanship should have the following properties: a reasonably uniform cross section with a flat or slightly bulging face and a fairly smooth surface; reasonably straight edges flowing into the base metal; a well-defined crater about 1/16-inch deep; a surface with ridges or ripples spaced quite closely and uniformly after being cleaned with a wire brush; and a bright surface of uniform color.

Easily seen defects in a weld, their causes, and the required remedies are as follows:

1. Overlap, or the edge of the weld metal being loose and running over the base metal,* caused by poor fusion.

2. Undercutting, caused by not having enough electrode metal. The weld should be thoroughly cleaned and built up to standard size with additional weld metal.

3. Shallow craters; caused by not getting enough penetration. Unless the weld is for sealing purposes only, it should be cut out and a new weld made.

4. Pits, porosity, and gas pockets; caused by improper procedure. The weld should be cut out and a new weld made.

5. Slag inclusions and oxide inclusions; caused by improper procedure. Unless the weld is for sealing purposes only, it should be cut out and a new weld made.

6. Spatters; caused by too long an arc (if large and scattered over a wide area) or by poor fusion without enough penetration. The weld should be thoroughly checked, and a piece of weld should be cut out and checked if there is any doubt about the quality of the weld.

7. Irregular spacing of ridges, caused by variation in the speed of welding. The weld may be accepted unless the arc has been jumped forward so as to leave a space with not enough penetration.

Inspection of Welds

68. The Inspector must be certain that an electrode* is used only in its proper position and with the specified type and polarity of welding current. Also, he must keep a record of all welders and their qualifications, the results of any qualification tests that may have been made, and other important information.

Each weld should be inspected after the slag has been removed. The inexperienced Inspector will be able to do a better job on welded work if he watches how welds are made and examines carefully a large number of finished welds. When making a visual inspection of welds and the base metal parts for cracks and other defects, the Inspector should use a strong light and a magnifying glass. The Inspector must mark each weld he has inspected and approved in such a way that it can be easily identified.

The size and length of each fillet* weld must be compared with the dimensions shown on the Drawings. The size or length may be slightly oversize or longer than specified.

Preparation of Steel for Painting

69. The purpose of painting steelwork is to coat the surface with a protective film that will prevent rapid rusting. A great deal of time and money has been spent in developing paints which will furnish good protection. In order that paint may be effective, however, it must be applied to the steelwork properly.

Ordinarily, the main steel members of a structure are painted in the shop before they are shipped to the job site. At least one coat of paint must be applied in the field. Before paint is applied to steel, the surface must be clean, dry, and fairly warm. To be clean, the surface must be free from rust, loose or hard mill scale, loose paint, dirt, oil, grease, or other foreign material. If paint is applied to a surface on which rust forms later, the paint will crack and peel off because of the pressure produced in the rusting process. Also rust may seriously reduce the strength of a steel member.

There are three approved methods of cleaning steel: hand cleaning, sand blasting, and flame cleaning. Hand cleaning is most used in the field. Rust, scale, loose paint, and dirt are removed by means of power-driven metal brushes or by hand tools such as scrapers, chisels, and hammers. Oil and grease are removed by rubbing with a rag moistened with gasoline or benzine. If an existing, firmly clinging film of paint is to be left in place around an area where cleaning has been completed, the edges of the existing film should be smoothed with sandpaper so that the finished painted surface will have a pleasing appearance.

Paint should not be applied to steel under any of the following conditions: when the air temperature is below 45 degrees F.; when there is mist in the air; when the surface of the metal is damp or covered with frost; or when

the metal is hot enough to cause the paint to blister, to produce a porous film, or to cause the pigment* in the paint to separate from the vehicle.* Where more than one coat of paint is to be applied, each coat must be thoroughly dry before the next coat is put on.

Where concrete is to be placed near steel before the metal is painted, cleaning of the steel should not be started until all the concrete has been put in the forms. Any concrete that drips onto the steel should be removed before it hardens.

Inspection of Paint and Prepared Surface

70. The Inspector should examine paint before it is used to make sure that it meets the Specification requirements and is in good condition. All containers should be kept closed tightly until the paint is to be used. If the lid of a container has become loosened while being shipped from the factory, that container should be rejected. Paint should also be rejected if it has become stale in storage.

When the steel has been erected and cleaned, the Inspector should examine all rivets driven in the field, all bolts placed, all welds, and all surfaces not coated with paint in the shop. As soon as possible after the Inspector has approved the workmanship at these places, the bare metal should be given one coat of paint of the kind used in the shop. If the Inspector comes across a member that was not painted in the shop, he should ask the Inspector-in-Charge for instructions in regard to the use of a prime coat before the field coat is applied. The Inspector can find out if a film of shop paint is sound or loose by trying to insert a knife blade under the paint at an edge.

A system should be followed in cleaning the steel so that the workmen can clean a member or a certain part and can have it inspected just before it is to be painted. If the shop paint must be removed, only as much surface should be cleaned in one day as can be painted on that day. Rusting of the steel can start very quickly in damp air.

Application of Paint in Field

71. To get a good job, thorough mixing of paint before it is applied is essential. Also, the paint should be stirred frequently while the steelwork is being painted. A mechanical mixer should be used for stirring the paint. In addition to the shop coat, steelwork should be given two coats of paint in the field, with the colors specified.

The paint should usually be applied to the steelwork with hand brushes. It should be spread smoothly and uniformly. If the film of paint is too thick, it will run and sag; and as the film ages, checks and wrinkles will generally be formed. If the film is too thin, it will not give the desired protection. Paint should be worked into all corners, joints, and other places hard to get at.

For the first field coat, paint is applied first only to such surfaces as rivet heads, bolt heads and nuts, and edges of plates, angles, and other rolled shapes. Then, as soon as this paint has dried thoroughly, a coat is applied to all surfaces; the spots coated in the first operation are painted again in the second operation.

Painting should be done systematically, preferably by painters working in small groups. Inspection will be simplified if the groups work reasonably close together and follow a definite system. Generally one coat should be completed on a suitable area before work on another coat begins. Usually, the highest members should be painted first. Any paint that drips on the lower members can be covered smoothly when they are painted.

Paint should not be applied under unfavorable weather conditions. If a member is too hot, the paint will spread too thin. Trying to apply a thicker coat will probably cause the paint to run. In cool weather, the paint must be brushed out thoroughly to get it to stick to the steel, and more time is needed for the paint to dry.

Spray Painting

72. When spray painting is permitted, the work should be done by experienced men with approved equipment. The paint should be applied in a uniform layer. The pattern to be followed in applying the paint should make it possible to get a uniform thickness not less than that obtained by a proper brush coating. There must be some overlapping at the edges of strips covered on successive strokes of the spray gun.

The spray gun should be held at right angles to the surface being painted and at the correct distance away from it. The air pressure in the gun must be high enough to atomize the paint properly, but should not be so high that there will be excessive fogging, evaporation of solvent, or loss of paint by overspraying. The painter should release the trigger of the gun at the end of each stroke. All runs and sags must be brushed out right away, or the paint must be removed and the surface repainted. All small cracks and cavities, such as back of crimped stiffeners and around splice plates, etc., which were not sealed in a watertight manner by the first coat of paint, must be filled with a pasty mixture of red lead and linseed oil which must be dry before the next coat is applied.

Inspection of Painting

73. Painting of steelwork must be inspected carefully and thoroughly. The Inspector should see to it that the work is done in accordance with the Specification requirements. He should not permit paint to be applied until the steel has been cleaned properly and is dry and at a suitable temperature. He must also consider the temperature and dampness of the air. The Inspector can determine if a previous coat of paint is dry enough by scratching the film with his fingernail. If the paint tends to tear or roll up when scratched, it is not dry enough to be covered with the next coat.

After the last coat of paint has been applied and allowed to dry thoroughly, a final inspection should be made. Many defects in painting do not show up until the film has dried. In this final inspection, the Inspector must make sure that all the required coats have been applied to all parts of the surfaces and that there are no scratches or other defects in the finished film.

Retaining Walls

74. A retaining wall* is needed where it is not practical to allow earth, loose rock, or similar material to take its natural slope for the entire depth of an excavation or embankment.

For example, retaining walls are built on both sides of an expressway which runs through a city below the usual street level. A retaining wall may also be built in open country where a high embankment or a deep cut is required and the width of the right-of-way is limited.

Retaining walls are usually of plain concrete or reinforced concrete. The base of a reinforced concrete wall is allowed to harden before the stem is placed. The keyway between the base and the stem may be either raised or depressed. A raised keyway is usually better, because there is no groove in which water or trash will collect. Steel dowels help tie the stem to the base. A long retaining wall is generally built in sections with vertical expansion joints between the sections. It is the usual practice to place the concrete in alternate sections first, and to construct the other sections after the concrete in the first sections has hardened.

Retaining walls are staked out by the survey corps or by the Inspector-in-Charge. The foundation material on which a retaining wall will rest must be inspected and approved. Where a large wall will not rest on rock, the foundation must be approved by the District Bridge Engineer. If the height of any wall must be changed from that shown on the Drawings in order to get a good foundation, the conditions must be brought to the attention of the District Bridge Engineer.

The Inspector must see to it that the foundation is excavated to the required depth, and that firm bearing is obtained for the base of the wall. When the excavation is completed, and before any concrete is placed, the Inspector must measure and record the length, depth, and width of the excavation. These distances must not be less than those shown on the Drawings.

A retaining wall may overturn, slide, or be crushed if the backfill behind it is not placed right. Suitable backfill material must be used, and it must be placed in layers no thicker than specified and thoroughly compacted. Sometimes, the Drawings call for stone backfill in contact with the back of the wall to promote drainage. Where this type of construction is specified, special attention must be given to the location and number of weepholes* through the wall to permit water to escape from the stone backfill. Impervious material should be used in the backfill below the elevations of

the bottoms of the weep holes, in order that the water will be forced to run through the weep holes and will not drain into the soil below them. If water does drain into the soil below the wall, the foundation may be weakened and the wall may fail. The Inspector should make sure that the backfill is placed properly.

<u>Slope Walls, Spillways, and Tree Walls</u>

75. Cement concrete, precast concrete blocks, as well as plain or mortared stone may be used for slope walls* or spillways*. Details of their construction are shown on Department Standards. A smooth and well-compacted bed for the wall or spillway must be provided at the required depth below the finished surface of the slope. All soft and unsuitable material must be removed from the bed.

Shaly, soft, or unsound stone must not be used in a stone slope wall or spillway. The pieces of stone must be well bedded and laid with no empty spaces between them. Each stone must be thick enough to extend through the entire depth of the wall or spillway floor. Small projections on stones may be smoothed off after the stones are placed.

Care must always be taken to prevent surface water from undermining a spillway or wall and causing it to fail. A vertical cut-off wall at the toe of the slope should go deep enough into the ground to keep water from getting under the slope wall or spillway. The kind of soil must be considered. If the soil may be washed away easily, it may be necessary to pave a short section of the ditch or gully at the toe of the slope, or to increase the depth of the cut-off wall. The Inspector-in-Charge should bring such a condition to the attention of the Assistant District Construction Engineer.

Accurate sketches showing all dimensions for a slope wall or spillway must be prepared by the Inspector-in-Charge.

<u>Stone and Brick Masonry</u>

76. Ashlar rubble masonry*, cement rubble masonry*, or brick masonry is often used as a facing for a concrete abutment or pier that is exposed to water which would weaken or destroy the concrete. A masonry facing is generally needed where the water is acid because of drainage from coal deposits or from densely wooded areas. The type and dimensions of a masonry facing are shown on the Drawings. Where masonry is used for a facing, the mortar joints must be as narrow as possible.

An ashlar rubble facing is used only when a very neat appearance is wanted. Great care must be taken in choosing and preparing the stones and in constructing the facing. The Inspector must examine the construction closely to make sure that the detailed requirements of the Specifications are met.

To make sure that bricks meet the Specification requirements, a sample of ten bricks in all must be taken from different places in each shipment (either truck or railroad car) and sent to the Laboratory for testing.

The Specifications require that the joints in brick masonry be completely filled with mortar. To meet this requirement, each brick must be laid by the "shove-joint" method. That is, the end of each brick must be completely covered with mortar, and the brick must be shoved into place lengthwise so that mortar is squeezed out of the joint.

If bricks are laid in cold weather, with the permission of the Engineer, the Contractor must furnish protection which will prevent the temperature of the bricks and the backing from falling below 32 degrees F. The temperature of the air around the masonry should be kept above 40 degrees F.

Waterproofing

77. The Drawings or Specifications may require that concrete surfaces which will be in contact with the ground in service be waterproofed, in order to seal the surface of the concrete, and thus prolong the life of the concrete and prevent rusting of the steel reinforcement. All portions of a waterproofed surface must be protected equally. If there is a thin spot in the waterproofing, water will enter the concrete at this place first.

A ply of waterproofing consists of a layer of fabric and a coat of asphalt on tar. Each ply must have uniform thickness. Care must be used in applying the waterproofing at expansion joints, and provision must always be made for slight movement of the structure at a joint. Expansion joints must sometimes be sealed with asphalt cement before waterproofing is placed over them. This filling in a joint will act as a base to carry the fabric in the waterproofing across the joint. Otherwise, the fabric might be pressed into the joint and might break when the structure expands or contracts. However, the fabric must be wrinkled or rolled at each expansion joint after the joint has been properly filled.

At a drainage opening in a waterproofed surface, great care must be taken to prevent leakage through the waterproofing. Where waterproofing is laid on a vertical or sloping surface, the upper edge of the waterproofing should be sealed in a groove in the surface or carried under a coping.*

Where backfill is to be in contact with a waterproofed surface, the material must be placed carefully, so as not to damage the waterproofing. Stones, small hard lumps of earth, or other material thrown on or against a waterproofed surface may puncture the waterproofing and let water get behind it. Selected materials should be placed in contact with the waterproofing, and stones and other sharp particles should be kept some distance back so that a roller or mechanical tamper will not force them through the fine material and into or through the waterproofing.

Removal of Existing Bridge

78. When materials from an existing bridge are to be saved for the use of the Department or for other purposes, the Inspector-in-Charge must warn the Contractor to remove and store them carefully.

The District Bridge Engineer will tell the Inspector-in-Charge and the Contractor what is to be done with the material. When a steel member is to be saved, the Contractor must handle it so as not to cause permanent bending or other damage.

Stream-Bed Paving

79. A stream bed may be paved with plain or reinforced concrete or plain or mortared rubble. The paving is usually needed at a drainage structure, to prevent wearing or washing away of the stream bed under and next to the structure. Drawings will show the area to be paved and the thickness, and type of paving. Cutoff walls are built at the ends of the paving where necessary to prevent undermining of the paving. If field conditions require a change in the type or amount of paving, or in the locations and size of the cutoff walls, the situation should be discussed with the Assistant District Construction Engineer before any changes are made, and his instructions should be followed.

Unsuitable material found in the bed should be removed and replaced with approved material. Provision must be made for expansion in concrete or mortared rubble paving. The section and grade of the proposed paving must be determined from the Drawings, and batter boards and lines set accurately. Water normally flowing in the stream bed, or water that would flow there during rain, must be diverted from the area to be paved.

The Inspector must check the construction process to see that the work meets the detailed requirements of the Specifications. Laboratory approval of stones to be used in rubble paving must be obtained before they are used in the work.

Sketches should be made and actual dimensions recorded by the Inspector-in-Charge, to serve as the basis for the final computation of paving quantities.

Steel-Beam Bridge Flooring

80. The Inspector must examine all flooring as soon as it is delivered. Any defects should be reported to the District Bridge Engineer immediately. The Inspector should also make sure that the flooring is installed properly, making certain that the welding is in accordance with the plans.

The beams of the flooring are welded to the stringers* of the bridge deck in the field. Each section must be clamped securely to the stringers while the welding is being done, and be left in place until the welds cool.

If possible, the bottom of each beam of the flooring should bear on the entire width of the upper flange of each stringer. The field welds must be made by a welder who has been qualified by the Department and in accordance with the Drawings and Specifications.

The concrete for filled flooring must be mixed, placed, vibrated, finished, and cured in accordance with Specification requirements. Vibration may be applied directly to the steel flooring.

Inspection procedures for concrete paving are, in general, applicable to the concrete in steel-beam flooring. The finished concrete surface must be straightedged to check its smoothness and riding qualities. As for other types of structures, the Inspector should enter correct dimensions, quantities, and any essential notes in the Estimate Book.

Pressure Mortar Pointing and Surfacing

81. Mortar* applied under pressure is often used to provide a protective covering for a steel member, to provide a finishing coat on a concrete or masonry surface, or to point* the joints in masonry. The process is commonly called Guniting,* and the mortar is known as Gunite.* Air-entraining cement should be used in Gunite.

The equipment for Guniting must be capable of shooting mortar of uniform quality from a mixing nozzle with such speed that all or nearly all of the mortar will stick to the surface to be covered and little or no material will rebound. The speed of the stream of mortar should be shown by a meter attached to the equipment.

The mortar applied to a rolled steel shape is usually reinforced with welded wire fabric, which is fastened to the steel shape in its proper position before the mortar is applied. The steel reinforcement must be bent to the proper shape before it is put in place and should fit the member to be covered as well as possible. It should not be in contact with the member, but should be about 3/4-inch away.

If a thick covering of Gunite is needed to build up a part of a structure, more than one layer of reinforcement may be used. Too many layers, however, may interfere with the placing of the Gunite and may cause planes of weakness in the mortar.

Application of Gunite

82. A surface to be covered with Gunite must be clean. Rust, mill scale, grease, or other foreign material may spoil the bond between the Gunite and the surface to be coated. The equipment for applying the Gunite should be adjusted so that the moisture content of the mortar, the pressure at the nozzle, and the speed of the stream shot from the nozzle are as specified. If the mixture does not stick to the surface properly, a change may be necessary. However, any change must be approved by the Assistant District Construction Engineer, and must be made before the final or "flash" coat of mortar is applied. If it is necessary to hold the nozzle so close to the surface to be coated that too much material rebounds at the specified pressure, the pressure should be reduced.

Gunite is applied in thin layers. When Gunite is being applied near another surface that is not to be coated, care must be taken to prevent material that rebounds from getting on this surface. For example, if Gunite is being applied to a surface over a railroad track, material that rebounds will dirty the railroad ballast very quickly, unless the track areas are covered or protected. Also, loose material trapped in the Gunite itself must be removed before it is covered by the next layer or mortar.

Gunite may be applied in cold weather, but only with the written permission of the District Construction Engineer. Heating equipment, housing, and other protection must be provided and approved. Gunite is usually put on parts of structures which cannot be enclosed easily and which cannot be heated by using salamanders,* bonfires, and similar sources of heat. In cold weather, it is usually necessary to construct housing around the work and to provide the required amount of heat by using steam.

Inspection of Guniting

83. The Inspector must see to it that the materials for Gunite meet the Specification requirements, and that the work is done in accordance with the detailed requirements of the Specifications. Almost continuous inspection is necessary on this kind of construction. Also, before Guniting is started, it is the Inspector's duty to make sure that all nearby surfaces are protected from material that may rebound. The Inspector must keep a daily record of the materials used for Guniting and the area covered with Gunite.

Cribbing

84. In general, cribbing is made up of a series of hollow bins filled with rock or other suitable material. The framework for the bins usually consists of members of reinforced concrete, metal or timber.

Cribbing must be staked out in the same way as other retaining walls. Allowance must be made for the correct batter. The positions of the crib members first placed must be checked carefully by the Inspector, as the stability and batter of the whole crib assembly will depend on the accuracy with which these members are set.

Reinforced Concrete Cribbing

85. Concrete cribbing members must be made and placed in accordance with the detailed requirements of the Specifications and as shown on the Drawings. The bottom members must be supported on a firm bed, and the foundation must be approved before these members are placed.

If footings are needed under the bottom stretchers,* concrete blocks should be cast in place to support the ends of pairs of abutting stretchers. The concrete in these blocks must be protected and cured for at least 7 days before the stretchers are set in place. Between the blocks, the stretchers should be in contact with beds prepared by excavation. The bottom stretchers may be supported in some other approved way, but care must be taken to provide suitable bearing.

One face of each reinforced concrete stretcher is marked to show that the stretcher should be placed with this face toward the outside of the crib. It is important to lay the stretcher in the proper position, because additional steel reinforcement is placed near this face to resist the horizontal pressure exerted by the filling material. After several stretchers in the bottom tier of the front have been carefully

put in place, the opposite stretchers in the bottom tier of the back should be laid. Then the headers* which rest on these bottom stretchers should be placed, and the crib should be built up by laying alternate tiers of stretchers and headers. A cushion of expansion joint material 1/4-inch thick should be inserted between each stretcher and header to cover the entire bearing area of one member on the other. Sometimes, drift bolts are used to connect the members.

Metal Cribbing

86. Columns for metal cribbing having the required batter are set in pairs, one in the front wall of the cribbing and the other directly opposite the first one in the rear wall. The distance along the cribbing between pairs of columns corresponds to the lengths of the stretchers or stringers, which overlap one another vertically to form a solid face. The columns of each pair are kept the proper distance apart by headers (or spacers), which also overlap vertically. Each column rests on a metal base plate. The columns will have the right batter if the base plates are set with the correct slope. Each stretcher is fastened to the columns through connecting channels attached to the stretcher at each end.

In excavating for metal cribbing, the earth is first graded level, at the elevation of the finished ground line at the front face of the cribbing, from the front face to a point a few inches beyond the rear limit of the cribbing. The excavated earth can be stored in front of the cribbing or placed in partly erected bins. After this first grading has been completed, trenches are dug wide and deep enough to permit the base plates and the bottom stretchers and headers to be placed.

To erect metal cribbing, a number of base plates are spaced along the front face of the cribbing, and the rear base plates are set behind them at the proper distance measured at right angles to the front face of the cribbing. The Inspector must make sure that all bearing plates are carefully and accurately set.

Front and rear columns are then set on the base plates, and are held in position until the bottom header and one or two other headers can be set between the columns and this cross frame is temporarily bolted and braced so that it will stand alone. Other cross frames are set up on the base plates in the same way, and the cross frames are connected by the stretchers.

As the cribbing is built up by adding more headers and stretchers, the headers should be kept at least one course higher than the stretchers to make bolting easier and to hold the front and rear columns parallel. Nuts should not be tightened until the bolts are in position on both flanges of the column.

If the columns must be spliced, the fill material is placed in the bins to within a few inches of the splice, to make a working platform for setting the upper parts of the columns. Before the upper part of a column is placed, the lower halves of the connecting channels on the

stretchers and the column splice plate should be tightly bolted to the lower part of the column. It will make the bolting of the upper part of the column easier if one or two headers above the splice are put in place before the upper part of the column is spliced to the lower part.

To give the cribbing a finished appearance, a column cap is bolted to the column after the top connecting channels have been put in place.

Before the last few bolts are put in the front stretchers at the top of the cribbing, stretcher stiffeners are inserted between the top flanges of the stretchers and the connecting channels.

Filling Cribs

87. When enough cribbing has been put together, filling with granular material can begin. The granular material placed in the bins must meet Specification requirements to insure proper drainage. Since shale breaks down into fine material that clogs up the voids in the granular material and stops drainage, the use of shale for backfill must not be allowed. The granular material must be spread out and tamped in layers not more than 12 inches thick.

Cribbing Quantities

88. Complete measurements for cribbing, excavation, and concrete must be made and recorded, and compared with the values called for by the Drawings. The quantities must be computed by the Inspector-in-Charge for estimate purposes, and all measurements, sketches, and computations are sent to the District Office to be checked for final quantities. The Contractor is not entitled to payment for any additional material placed, or additional work done, to make the construction of the cribbing easier.

CHAPTER IX

CONCRETE AND STEEL STRUCTURES

CHECK LIST OF IMPORTANT ITEMS

Have all footings been checked for position and firm condition of bottom of excavation before concrete is placed?

Have all driven piles been checked for position? Has bearing capacity been checked at full hammer speed?

Have shells of all cast-in-place piles been checked to make sure that they are undamaged and are free from mud and water before concrete is placed? Is placing of concrete checked constantly to make sure that each shell is filled solidly with concrete? Are records being kept of the concrete placed in each pile shell, or in groups of pile shells?

Has all form work been double checked for line and grade? Are they firmly supported by falsework to the proper camber? Are all chamfer strips in place? Are bottoms of all forms free from water, ice, sawdust, chips, or any other foreign material?

Has all reinforcing steel been solidly tied in proper position? Have all splices been checked for position and overlap? Has clear distance at all points between rebars and form been checked by sliding a wood gage between steel and form?

Have arrangements been made to place concrete in the forms without use of long chutes, flowing concrete along the form, or dropping concrete more than 4 feet?

Are additional vibrators and other equipment on hand in case of breakdown? Are carpenters and materials on hand to take care of a break in the forms? In case of work stoppage, has permissible location of emergency construction joints been planned?

Has Contractor instructed workmen in proper methods of placing, spading and vibrating concrete?

Have plans been made for equipment and finishers that will insure a smooth riding bridge deck?

Have provisions been made to cure and control temperature of concrete? Are suitable thermometers on hand to check temperatures of concrete and air?

Have all steel members been checked for dimensions and condition?

Is all steel being constantly checked to make sure that it is drawn tight before riveting? Are all rivets being systematically checked for tightness?

Is workmanship of all welders being checked? Have welds been actually checked?

Is all steel properly prepared for painting? Is paint thoroughly mixed? Is each coat of paint being applied so as to best serve the purpose of protecting the steel bars from rusting?

CHAPTER X

MISCELLANEOUS CONSTRUCTION ITEMS

Curbs, Gutters, Sidewalks, Guard Fences, Right-of-Way Fences, and Barricades

CONTENTS

CHAPTER X

MISCELLANEOUS CONSTRUCTIONS ITEMS

Curbs, Gutters, Sidewalks, Guard Fences, Right-of-Way Fences, and Barricades

Importance of Inspection of Minor Items

1. The curbs, gutters, sidewalks, and fences are often the last construction items on a highway project. If the Contract is behind schedule, there may be a tendency to rush them to completion. However, the public looks at them very closely. If lines and grades are not set and followed carefully, or if a neat surface finish is not obtained, the work will be criticized. For this reason, very careful inspection is required. No matter how little time the Contractor has to do the job, the Inspector must see to it that line and grades are as shown on the plans; the specified materials are used; workmanship is as required by the Specifications; concrete is properly cured; and the site of the work is in good condition and cleaned up before final inspection.

General Features of Concrete Curbs

2. Curbs show the limits of the roadway and prevent surface water from running off the edges of the pavement between outlets. The materials most used for curbs are cement concrete and stone, but bituminous concrete is used in some places. Concrete curbs may be separate structures or may be cast in one piece with a concrete base course or surface course. Details of curb construction are shown on sheet SD-10 of the Standard Drawings. The information on curbs given in this Manual pertains mainly to separate cement concrete curbs.

When next to a flexible base the curbs should be built before the base is placed. A concrete base or concrete pavement should be completed before the curb is built. This order of construction should not be changed without the permission of the Assistant District Construction Engineer.

If the curbs are built before the paving is placed, the line and grade of each curb must be checked carefully. If there is any mistake in line, the pavement will not meet the curb uniformly. A mistake in curb grade will be carried into the pavement. A curb must always be built on firm, fully compacted material, so that there will be no chance of settlement. The Contractor should never be permitted to support even a short section of curb on material loosely piled to bring the curb up to grade.

When subsurface water may drain toward the roadway, foundation underdrain should be used. It is usually placed beneath the curb. However, the Contractor may want to shift the underdrain away from the curb in order to get good support for the pins that support the curb forms. If the Assistant District Construction Engineer approves such a shift, the portions of the subgrade under the curbs should be graded so as to avoid trapping of water. Excavation for the curb and the underdrain should be done at the same time. The foundation underdrain should not extend beneath the pavement.

Openings in Curb

3. Where a driveway enters a street, the curb may be made lower for the width of the opening. At a driveway, the height of the curb at its face should not be more than 2 inches, and the height at the back should be 1 inch more than that at the face. Between a low curb at a driveway and adjacent curb of regular height, there should be a sloping section about 18 inches long. A low or sloping section of curb is paid for at the same price per foot as regular curb.

Where there are buildings with roof drains and downspouts, openings for these drains may have to extend through the curb. Such openings should be provided when shown on Drawings or when directed by the Assistant District Construction Engineer.

Line and Grade for Curb

4. Stakes for line and grade of a curb should be set not more than 50 feet apart, and should be closer where there is a change in grade or a short curve. It is usually best to show the grade for the top of the curb by offset stakes set between 2 and 3 feet from the back of the curb.

The surface of the compacted subgrade or subbase should be left slightly high, so that it can be trimmed down to final grade when the curb forms are being set. If the surface of the subgrade or subbase under the curb is low, additional subgrade or subbase material having the proper moisture content should be used for backfill. This material must be compacted fully. Curb forms should never be set on material not fully compacted.

Forms for a concrete curb must be solidly braced, so that there is no chance of movement when the concrete is placed. The forms should be checked for line and grade by measurements from the offset stakes and by sighting along the top of the forms. The Inspector must check the distance across the roadway between forms at least every 100 feet. On a curve the forms must be shaped so that the curb will have a good appearance. There must be no sharp break in the alignment at a joint between form sections. If a section of form is found to be bent or twisted, it must be removed and replaced with one which meets the requirements of the Specifications. The Inspector must mark the forms at all places where the height of the curb is to be reduced, where drains are to pass through the curb, and where curb type inlets (if used) are to be located.

Expansion Joints in Concrete Curbs

5. Except in the case of cement concrete curb, made in one piece with the concrete base, an expansion joint filled with premolded material 1/4 or 1/2 inch thick is to be provided between each curb and a concrete pavement, as shown on the Drawings or as directed. The Specifications also require that 1/4 inch premolded expansion-joint material be placed at each end of a curved portion of a curb, and that two plain (not deformed) steel bars 1/2 inch in diameter and 24 inches long be spaced horizontally,as required,in the concrete

at each end of the curve. These bars are called dowels. To allow movement of the curb at the expansion joint, one half of each bar is to be coated with some material, such as graphite paste, which will prevent the concrete from sticking to the bar. The end of this half of the bar must be covered with a metal cap which will give a positive clearance of at least 1/2 inch at the end of the bar and which will stay in the proper position while the concrete is placed.

Placing Concrete in Forms

6. Concrete for a curb must meet all requirements of the Specifications. Ready-mixed concrete is usually used. Before concrete is placed in the forms, the forms should be lightly oiled, and the subgrade sprinkled with water so that it will not absorb water from the freshly placed concrete. Since concrete curb cannot be placed rapidly, the Inspector must make sure that water is not added to the concrete if it starts to stiffen before it is placed. Calcium chloride should not be added to the concrete unless its use is authorized by the Assistant District Construction Engineer. If its use is permitted, the quantity added must be checked carefully because too much calcium chloride can greatly shorten the life of the concrete in the curb.

Concrete should have the specified slump and should be placed in layers 4 to 5 inches deep. Each layer should be spaded or vibrated (when vibration is permitted by the Assistant District Construction Engineer) so that smooth surfaces will be seen when the forms are removed and little or no patching with mortar will be required. If the concrete is vibrated, the Inspector should see to it that the vibrator spud is not left in one place longer than 5 seconds. Over-vibration may cause too much mortar to be brought to the top of the form.

Completing Construction of Curb

7. After the concrete has been floated, and as soon as it has set enough to keep its shape after edging, the front edge of the curb should be rounded off to a 3/4 inch radius and the rear edge to a 1/4 inch radius, as required by the Specifications. Curing, usually with wet burlap, should start immediately, and arrangements must be made to keep the concrete moist at all times until the end of the curing period.

After the forms are removed and the concrete has been cured for the proper length of time, any fins or other projections should be removed by rubbing with a carborundum stone, and any honeycomb repaired with a 1:2 mortar. Brush finishing or plastering should not be permitted. When rubbing and patching have been completed, each joint should be checked to make sure that it is not bridged with mortar. No backfilling should be started until the concrete has been cured, in accordance with Specifications, for at least 7 days. Suitable material should be placed and compacted in 4-inch layers on both sides of the curb at the same time, so that the curb will not be tilted during the backfilling process.

Construction of Concrete Gutter or Curb and Gutter

8. Gutter locations shown on the Drawings are based on information obtained during preliminary inspection of the site. After rough grading is completed, the Inspector-in-Charge should study actual field conditions to see if surface water can be carried to an outlet in a better way, so that the cost of gutter construction can be reduced. The final location of any gutter must be approved by the Assistant District Construction Engineer. Details of gutter construction are shown on Sheet SD-10 of the Standard Drawings.

Except as noted in the Specifications, the duties of the Inspector are about the same for concrete gutter, or combined curb and gutter, as for concrete curb. The purpose of the gutter is to lead water to an outlet, and the Inspector must make sure that the gutter will contain no depressions in which pools of water may remain. He must also see to it that a substantial back form is used, to avoid "scalloping" of the gutter.

A watertight joint must be obtained between a concrete gutter and the pavement or structure next to it. When a concrete gutter is to be placed against the edge of a pavement or against the face of any structure, the Specifications require that the edge or face be painted with a heavy coat of bituminous material, such as an asphalt cutback. This coating material should be tacky when the concrete for the gutter is placed. When a concrete gutter is used along a concrete pavement, it is important that a transverse joint be placed in the gutter exactly in line with each existing joint in the pavement, and that each joint in the gutter be of the same type as the opposite joint in the pavement; that is, expansion and construction joints in the gutter should be matched with the same kind of joints in the pavement.

Checking Flow Line of Gutter

9. Concrete for a gutter, or combined curb and gutter, should be struck off and floated with great care, to get a good appearance and good drainage. The surface of the gutter should be checked very thoroughly with a 10-foot straightedge early in the finishing operation so that corrections can be made. If the curb and gutter are cast together, the straightedge should be used on the top and face of the curb as well as in the gutter.

To get a good appearance and a smooth flow of water at an inlet, culvert, or driveway, the surface of the gutter will have to be warped. The required shape at such a place should be discussed with the Assistant District Construction Engineer before the work is started.

Foundation for Cement Concrete Sidewalk

10. A concrete sidewalk must have a firm and well-drained foundation. During excavation for sidewalk construction, the subgrade should be checked for soft spots, particularly where a utility service crosses the sidewalk line. The backfill in such a service trench may not have been compacted fully. Any soft material should be dug out and replaced with good subgrade material which is fully compacted, so that settlement will not spoil the grade of the sidewalk.

Before a sidewalk is built, the Inspector should make sure that all valve boxes, water-meter boxes, manhole tops, and other utility installations are set to the proposed sidewalk grade. Also, premolded expansion-joint material 1/4 inch thick must be placed around all poles and structures.

After approved aggregate for the subbase has been spread to the proper depth and compacted so as to get the required thickness, and the forms for the concrete sidewalk have been set to grade, a scratch board or template should be used to make sure that the concrete will have the full required thickness. Where a driveway or an entrance allows traffic to cross the sidewalk area, the sidewalk is replaced by thicker pavement as required, of plain cement concrete. If the points of change are not shown on the plans, they should be located by the Assistant District Construction Engineer.

Construction of Concrete Sidewalk

11. Sidewalk forms are usually set so that the sidewalk will slope toward the street at a rate of 1/4 inch to the foot. When an adjustment must be made at a corner where streets on steep grades intersect, this sidewalk slope may have to be increased. However, the slope should never be more than 3/4 inch to the foot. At a driveway, it is best to carry the normal sidewalk slope across the driveway and to make any required adjustment behind the outside edge of the sidewalk. Even on this steeper portion of the driveway, the slope should not be more than about 1 inch to the foot. In any case, care must be taken to avoid the possibility of creating a high point on which today's long and low cars will drag.

Concrete sidewalk is placed in sections 30 feet long. Adjacent sections are separated by expansion-joint material which is 1/4 inch thick and extends through the full 4 inch thickness of the sidewalk slab. Before concrete is placed, the subbase (or the subgrade if subbase is omitted) should be wet down so that it will not absorb water from the concrete. The concrete should have the designed slump, and the surface should be brought to grade by tamping and scraping with screed that is in contact with the tops of the forms. Concrete must never be placed with excess water which is later absorbed by cement, or cement and sand, scattered over the finished surface of the sidewalk. The hardened material at the top will surely scale off. The concrete should be spaded with a mason's trowel along the sides of the forms and on both sides of the expansion-joint material. A gritty surface texture, produced by final floating with a wood float or with a wet push-broom (fine fiber) drag, is usually preferred.

Finishing Concrete Sidewalk

12. As soon as the concrete in a sidewalk has taken a set, it should be divided into blocks 5 feet long by scored transverse joints. If the sidewalk is more than 5 feet wide, a scored longitudinal joint also should be made in the center. Since these scored joints act as contraction joints to control cracking, they should be re-opened to a depth of at least one-fourth the thickness of the slab as soon as the concrete has set enough to keep the desired shape and not slump back into the joint. The Specifications require that the con-

crete around a pole, fire hydrant, or other similar object in the sidewalk area be scored in a block 8 inches wider than the object. These scorings should also be re-opened so that the concrete can be broken out along neat lines if the object has to be removed. The concrete at a joint or edge should be rounded off to a 1/4 inch radius with an edger.

The Contractor should have on hand enough protective covers of paper or plastic to protect all freshly placed concrete from rain. Initial curing with wet burlap or by some other specified method should be started as soon as finishing is completed and the concrete is firm enough not to be marred by the curing material. The Contractor must make arrangements to protect the concrete from accidental or mischievous damage. It is usually best to time operations so that concrete will take its final set during normal working hours.

Location of Guard Fence

13. Guard fence serves to warn drivers of a dangerous spot along the roadway and helps to make the road safer for the traveling public. Each stretch of fence must be located where it will serve its purpose best.

All types of guard fence consist of wood, steel, or reinforced concrete posts supporting rail elements. As soon as the rough grading is completed, the Assistant District Construction Engineer will decide on the general layout of the guard fence so that the Contractor can order his material. However, the Contractor should be warned that slight changes may have to be made later. After the shoulders have been completed, the Assistant District Construction Engineer and the Inspector-in-Charge should locate the ends of each section of guard fence accurately. The Inspector-in-Charge should give special attention to curved sections of steel-plate guard rail, if they are needed, because they should be ordered as soon as possible.

Construction of Guard Fence

14. Guard fence should have a neat appearance. For this reason, holes for posts should be located accurately. The positions of the posts for steel-plate guard rail are of special importance, because the slots in the plates must be centered on the posts, in order that the plates may expand and contract without loosening the posts. If water enters the space around a loosened post, the whole installation can be weakened. Holes for posts should be just enough larger than the posts to permit the backfill material to be tamped in 4 inch layers with a suitable tool. The Inspector should not allow the use of oversize holes.

Steel-plate guard rail can usually be set to correct line and grade most easily if the plates are assembled while the posts are still loose in the holes and the posts are adjusted to both line and grade as the holes are backfilled. The line and grade of guard fence should look smooth to a motorist traveling in the outside lane. For this reason, the tops of the last two or three posts at a flared end of a length of fence may be lowered slightly, with the last as much as 3 inches below a line across the tops of the normal posts. The Inspector should check all posts during installation to make sure that they are embedded far enough in the ground and are plumb.

Except when the rail of a guard fence is anchored to a bridge, the Standard Drawings require that the last three wooden posts at each end of a section of fence have concrete collars that meet approved Department standards. The concrete should be brought above the surface of the shoulder and rounded off so that it will not collect water.

In cable-type guard rail expansion turnbuckles should be spaced at distances set by the Specifications to allow for take-up. When the fence is being installed, the turnbuckles should be tightened until the cable is taut. If the air temperature is above 60 degrees F. at the time, they should then be loosened to allow for contraction of the cable during cold weather.

Before the fencing crew leaves the site of the work, the Inspector should make sure that the shoulders are redressed and all trash or left-over material is removed.

<u>Right-of-Way Fence</u>

15. The purpose of right-of-way fence is to control access to a highway. Type 1 or Type 2 fence is made of wire fabric. Details are shown on the Contract Drawings and Standard Drawings, and on shop drawings where required. The Inspector-in-Charge should look over, on the site, all proposed access openings to make sure that access is physically possible at the locations shown. If changes are necessary, or if additional walk gates are necessary for maintenance purposes, the Assistant District Construction Engineer should be consulted.

Spacing of posts is usually the distance between centers of posts. The spacing shown on the plans should be checked by the Inspector. Where the total length of a single run does not permit all the posts to be spaced evenly, at the specified distance between centers, the end, corner, and brace posts should be set according to plan. The line posts should then be evenly spaced, but the spacing must not be more than that specified.

All posts for Type 1 fence, and the end, corner, and pull posts for Type 2 fence, must be set in concrete. The surface of the concrete in the post holes should be slightly above the nearby ground and rounded to shed water. The alignment of the posts should be checked with a stringline, and a carpenter's level should be used to see that each post is plumb.

The wire is usually placed on the roadway side of the posts. It must be stretched tightly so that there will be no slack edges or warped sections. The clearance between the bottom of the fabric and the ground must not be greater than that shown on the drawings, in order to prevent children and small animals from crawling under the fence. The Specifications permit cut or fill up to 6 inches in order to maintain clearance. As far as possible, however, high spots should be cut down, because the surface will then be more stable than when low places are filled in.

Where the fence crosses a stream or a drainage area, the Assistant District Construction Engineer should be consulted for methods of adjusting the fence installation to meet the field conditions. The fencing must not be placed in such a way that it might collect driftwood and cause flooding.

Permanent Barricades

16. The purpose of a permanent barricade is to block off a road or a portion of a road that is to be closed to public traffic. Details of construction of barricades are shown on the Standard Drawings.

CHAPTER XI

MATERIAL CONTROL

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CHAPTER XI

MATERIAL CONTROL

Need for Material Control

1. The Department has a responsibility to the taxpayers to see that all materials purchased and used for highway construction meet definite standards of quality, in order that the construction which results from placing these materials in position will be safe, long lasting, and present a good appearance. There is also a responsibility of the Department to the suppliers of materials to make sure that all suppliers are required to meet the same standards. It would not be fair to allow one supplier to furnish poor material, while another is required to furnish better material at the same price.

The Department meets these responsibilities by Material Control. Material Control starts with the setting up of standards in the form of Specifications. The Department knows what kinds of materials will give satisfactory results, and the Specifications describe these materials so that the suppliers will have a basis for setting fair prices.

The next step in Material Control is to make sure that each separate material, and also the construction that results when materials are used together, meets all the requirements of the Specifications. This step includes inspection, sampling, and testing; and the results of the tests must be compared with the standards all suppliers have to meet. If a material is rejected because it does not meet certain standards, the Department is not being unfair to the supplier of the material, but is acting fairly to all the suppliers and at the same time is seeing to it that the taxpayers are getting their money's worth. The Inspectors and other members of the Department whose duties relate to Material Control are hired by the taxpayers to make sure that all materials meet the standards and that all suppliers are treated fairly.

The Inspector at a plant or on the job is the most important man on the Material-Control team. He is the one who can best make sure that a material meets all requirements of the Specifications. He is like the umpire behind the plate in a baseball game, who is in the best position to call balls and strikes fairly. If an Inspector approves poor material, or unfairly rejects good material, he is not doing the job he is being paid for.

Standard Procedures

2. Certain methods of sampling and testing materials, which have been found best through experience, are called Standard Procedures. By following the Standard Procedures, an Inspector can sample and test each material the same way every time. Also, all Inspectors will use exactly the same methods. Some Standard Procedures are described in this Chapter or in other places in this Manual. Others are described in the Specifications, in Department Bulletins, or in other books dealing mainly with inspection and testing, such

NOTE: Words marked with an (*) are explained in a word list at the back of this book.

as those prepared by AASHO (American Association of State Highway Officials) or by ASTM (American Society for Testing Materials).

When a Standard Procedure has been worked out for a test, it must be followed exactly in order to get results that will be accurate and will have real meaning or significance. Every detail of the Standard Procedure must be considered important, as there is probably a good reason for each step called for. For instance, before the penetration of a sample of asphalt is measured, a requirement of AASHO procedure T49-53 is as follows: The sample must be freshly melted and then cooled in air for a period of time between 1 and 1-1/2 hours and kept in a water bath for another period between 1 and 1-1/2 hours. This requirement is included because some asphalt cements are thixotropic; that is, they harden like jelly when they are allowed to stand quietly for some time. A sample that has been allowed to stand overnight and is then tested without being melted and cooled as directed will probably have a much lower penetration than a sample of the same material which has been given the proper treatment.

For the Inspector to do his job well, he must be familiar with the Standard Procedures. Before he takes a sample or makes a test, the Inspector must be sure that he knows all the details of the Standard Procedure to be used. Whenever possible, he must take the sample or make the test exactly as required by this Standard Procedure. If, for some good reason, he cannot follow the Standard Procedure exactly, he should say so on his report and should describe just how the sample was taken or the test made. In case there is no Standard Procedure, the Inspector must inform the Inspector-in-Charge, and an approved procedure must be obtained from the Assistant Construction Engineer.

Because conditions may not be the same with somewhat different materials or in different places, a Standard Procedure does not always give complete details for taking a sample or making a test. In such a case the Inspector must use some judgment. He should follow the Standard Procedure as nearly as possible, and where the Standard Procedure cannot be followed or details are not given, he should follow what is generally considered good practice.

Importance of Sampling

3. To find out whether a material meets the requirements of the Specifications, a sample is taken and tests are made on it. A sample is only a small portion of a large amount of material called a "lot". For example, a stockpile* of sand for concrete may contain 100 tons, or 200,000 pounds, of material, while a sample used in a test may weigh only 1 pound.

Each sample for testing should be truly representative of the entire lot from which it is taken. When a representative sample is tested, the results of the test will be the same as those which would be obtained if all the material in the lot were tested. In order that a 1-pound sample of sand from a stockpile will be truly representative of all the material in the pile, the percentages passing each size of sieve found by testing the sample must be the same as the percentages which would have been found if the entire pile were passed through the sieves. Getting a representative sample requires a definite plan and the right tools, and considerable work is usually necessary.

Taking samples properly is the key to Material Control. If a sample is not taken in the right way, the test results will not be correct. Even though a test may have been continued for several hours and may have been made carefully with expensive and complicated testing machines or equipment the results may be false, and of no value, because the sample tested did not represent the material truly. Also, even though the results of a test may be shown by numbers indicating great precision*, the numbers may have no real meaning because the sample did not represent the material actually used in the construction. In other words, the test will not really show whether the material actually met the requirements of the Specifications or if the road or structure will give trouble because poor material was used.

The Inspector must make sure that every sample is truly representative of the lot of material from which it is taken. Taking a sample that is not representative wastes the time and money required to take it and test it. Worst of all, since the test result may be misleading, improper sampling may lead to unfair rejection of good material, or to the use of material which will give trouble later on.

Segregation of Materials

4. Almost all mixtures of materials used in construction tend to segregate* or to separate into unlike parts. Whether or not the Standard Procedure for sampling a mixture mentions segregation, one of the most important problems in obtaining a representative sample is to try to overcome the effects of segregation.

A few liquids, such as water and gasoline, are so composed that there is almost no tendency for segregation to occur. However, segregation does occur in most liquids used in construction, such as asphaltic cutbacks and emulsions, membrane curing compounds, paints, some asphalt cements, and some additives or admixtures. The material at the bottom of a tank or drum of such a liquid may not be the same as that at the top because the mixture has separated into layers.

The amount of segregation that occurs in a mixture of solid particles of various sizes depends mainly on the difference between the sizes of the largest and smallest particles. Some materials such as portland cement*, limestone filler*, and building sand, do not tend to segregate much because all the particles are of about the same size. However, if material for a base* containing 1-1/2 inch stone and some dust* and screenings* is placed in a stockpile, there will be much more of the fine material at the center and bottom of the pile than at the sides and top.

When aggregate* is stored in a cone-shaped stockpile formed by dropping all the material over the same point, the mixture usually segregates badly. The coarser particles go to the outside of the pile, while a core of finer material is left in the center. Building up of stockpiles by coning or depositing the material in one place is not permitted. Stockpiles must be built up and removed in four foot layers. Individual truckloads must be spotted close together over the stockpile area. When stockpiling with a crane or conveyor, each of the loads must be placed near each other, over

the area so that the thickness of the layer is uniform and in no instance more than four feet.

Bulldozers or other construction equipment, whether equipped with rubber tires or not, shall not be allowed to run up or on the stockpiled aggregates. Vibration from the bulldozer may cause finer particles to filter to the base of the pile, unbalancing the gradation. Continuous abrasive and grinding action of the tracks and/or the tires may break up the particles and cause degradation.

Any movement or relocation of the material must be made by an end loader or crane using caution that such operations do not result in segregation or contamination of the material.

Segregation is sometimes caused when a mixture is discharged from moving equipment or flows into place. At an asphalt plant, for instance, the aggregates are usually fed into the hot bins* in such a way that more coarse material goes to the side of a bin farther from the hot elevator*. Even a mixture of granular material and a plastic cement paste tends to segregate. For example, when a batch of hot-mix asphalt concrete* is dumped from the mixer into a truck, more of the coarse aggregate may go to the side of the truck. Also, if portland cement concrete* is allowed to flow into the forms from chutes*, more of the coarse aggregate* tends to go to the far side of the form unless a baffle* is placed at the outlet of the chute.

Segregation sometimes occurs in a mixture while it is being discharged from the mixer. Some of the segregation in hot-mix bituminous concrete in a truck is caused by coarse aggregate being thrown out of the mixture by the action of the blades of the mixer in the emptying operation. Also, when portland cement concrete is discharged from a truck mixer, the concrete first dumped from the mixing drum may contain more mortar* than does the concrete dumped last.

<u>Getting Representative Samples</u>

5. There are two general kinds of samples, which may be called grab samples and composite samples. When all of the material in a sample is taken from one place in a pile or a container, the sample is a grab sample. Such a sample may be considered representative of the entire lot for a material which does not tend to segregate. If it is known that the material in a lot is probably segregated, a composite sample should be obtained by taking small portions from various places in the lot and mixing these portions together. It is usually wise to get a composite sample from a lot of granular material, even if the material has not segregated much.

It is usually easy to take a grab sample of a material that does not tend to segregate. A sample of the proper size may be taken from any part of the lot. If a mixture of liquids tends to separate into layers, it is sometimes possible to remix the materials in some suitable way and to take a grab sample that may be considered representative of the entire lot. Otherwise, a composite sample should be taken in such a way that the right amount of material from each layer will be included.

When it is desired to get a composite sample of a mixture of granular materials that segregates easily, such as a base* mixture containing large particles and some dust and screenings, the best way is to take small portions of the mixture while the trucks or cars that carry it are being loaded or unloaded. If a composite sample of such a mixture must be gotten from a stockpile of the mixture, it should be obtained by digging into the sides of the pile in several places and taking small grab samples at various levels from the bottom to the top of each cut.

Another important feature in sampling a lot is to select the place or places in the lot from which samples should be taken. A sample should usually be taken without bias*. This means that the sampling point must be chosen at random*, or by chance, and not for any particular reason.

If a sample is taken from a certain place because the material in that part of the lot looks good, or bad, or even average, the sample will be biased. If, on the other hand, a stone is blindly tossed onto a pile of subbase material and a sample is taken at the exact point at which the stone lands, the location is chosen without bias, and the sample will be a random sample.

In some cases, a biased sample is taken purposely. If tests made on a sample taken from what is believed to be the poorest part of a unit of construction show satisfactory results, it is likely that the material in all parts of that unit of construction will meet the Specification requirements.

Separate Samples

6. Sometimes there is a large amount of a mixture in which segregation has occurred, and for some reason the materials will not be remixed before they are used. It is then best to take a number of separate samples from several different parts of the mixture, to identify each separate sample so as to show what part it represents, and to test each such sample. Each sample may be a composite sample, but portions of material from different parts should not be mixed together. The reason for this is that any batch of the mixture must meet the requirements of the Specifications at the time it is placed in any part of the construction.

For example, suppose that a large supply of crushed stone for road construction was stored in a long, narrow stockpile, and that the stone at one end was too coarse while the material at the other end was too fine. A composite sample obtained by mixing together small portions from different points along the entire length of the pile would show the average gradation but would not represent the material actually used in any part of the road. In the construction of the road, all the material used in one part would be taken from one place in the pile.

A large individual shipment of material, such as one in a railroad car or a barge, should be sampled separately, and the sample from each such shipment should be identified by lot or batch number, and should be stored separately for easy identification. Some materials, such as membrane curing compound, come to the job in drums with different dates or markings. It is clear that there is really more than one lot of such material, and a separate representative sample should be taken from each lot. Separate samples should also

be taken from different points in the face of a stone quarry, or from different points in a gravel pit or borrow pit, when materials from different parts will not be mixed before use.

Sampling Tools

7. For each material and sampling condition, there is one tool that is best for taking the sample. It is just as important to use the right tool for sampling as it is to use the right equipment for testing. No matter how accurate the testing equipment may be, the results of the test will not be true unless the sample was taken in the right way. In some cases, the Standard Procedures describe the tools to be used for taking samples. When they do not, a tool must be found that will take a fair sample. If the specified tool cannot be gotten, or if no specific* tool is called for, the tool that is used should be noted on the report or sample identification.

A scoop with high sides should always be used for taking or handling a sample of any dry granular material, freshly mixed concrete, or loose hot mix. If a flat tool, such as a shovel or trowel, were used for any of these materials, the coarse particles would roll off the edges of the tool, and the material left in the sample would have more fine particles than it should have. A scoop with straight, high sides and a flat bottom is best for sampling materials of many kinds. Such a tool can often be made by welding pieces of metal together on the job.

For sampling a bag of cement, a special tool called a "thief" can be used. This is made from an 18-inch piece of 1-inch pipe by cutting off one end on a slant, putting a cap on the other end, and boring a small hole in the pipe near the cap. To get a sample, the pipe is pushed through the filler valve found at one bottom corner of the bag, and the hole near the cap is left open to permit the escape of air while the pipe is being filled. As soon as the pipe is filled, the end of a finger is placed over the air-escape hole, and the tool is pulled out.

Another kind of thief can be used for sampling sand in a barge or a low stockpile, if the sand is damp. It is made from a piece of 1-1/2 inch pipe about 5 feet long by putting a T-shaped handle on one end and cutting a wide slot down the side. It is pushed slowly downward into the sand and turned at the same time until it is completely buried or the bottom of the material is reached. When it is pulled out, the sample in it represents the material in the full depth of penetration*. The sand can be easily pushed out of the thief with a stick by working through the slot.

All tools, equipment, and containers used for taking or holding samples must be perfectly clean. If a sample of asphalt cement is put in a can that has a little oil in it, the sample will be contaminated. This means that the sample has something in it which should not be there, and that the sample is not pure. The result of a test on such a sample is always wrong, and a wrong result usually leads to trouble. In general, tools and equipment used for taking or handling samples of asphalt hot mix should be heated to keep the asphalt from sticking to them. They must never be oiled. A tool can be kept

clean by warming and scraping it. If it is cleaned with a solvent, such as kerosene or fuel oil, it must be wiped clean and dried before it is used.

When a tool or container, such as a scoop or wheelbarrow, is used to take or handle a sample of concrete, it should be wetted and then wiped damp-dry. If it is too dry, it will absorb water from the concrete. It must be washed soon after being used, so that it will be clean when used again.

Size of Sample Taken

8. Usually the total size of a composite sample, after the many small portions have been taken and mixed together, should be as large as practical; that is, there should be as much material as can be readily handled and mixed. The best amount of material in a composite sample also depends on the sizes of the particles in the lot to be sampled. If there are many large particles in the lot, the weight of the sample must be great, so that it will include enough particles of each size. For instance, Table 1 gives the weights of field samples of aggregates of various sizes suggested by the AASHO in procedure T2-60.

TABLE 1 - Weight of Field Sample of Aggregate

Size of Largest Particles	Least Weight, in pounds, of Field Sample
No. 10	10
No. 4	10
3/8"	10
1/2"	20
3/4"	30
1"	50
1-1/2"	70
2"	90
2-1/2"	100
3"	125
3-1/2"	150

In any case, the composite sample must have enough material to provide a test sample of the right size for each of the required tests.

Size of Test Sample

9. The size of the sample needed for a test is often given in the Standard Procedure for the test. For instance, Table II gives the weights of samples needed for gradation tests of aggregates, as suggested by the AASHO in procedure T27-60. However, good judgment must be used in many cases.

TABLE II - Weight of Sample for Gradation Test of Aggregate

Largest Particle Size	Weight, in Pounds, of Sample
No. 8	0.2
No. 4	1.1
3/8"	2.2
1/2"	5.5
3/4"	11
1"	22
1-1/2"	33
2"	44
2-1/2"	55
3"	66
3-1/2"	77

The portion of a sample used at one time in a gradation test should be so chosen that the layer of material retained on any one sieve will not be thicker than about two or three times the size of particle retained. It may be necessary to pass the sample through the sieves in two or more portions and to combine the amounts retained on each sieve during the weighing operations.

Sometimes a test sample must be taken from material that is already in place in the construction. For example, a density test* on subbase is made on a sample removed from the compacted material. Such a sample must have enough of the largest particles in it. The test hole in subbase material containing 2-inch particles must therefore be much larger than the hole dug in a subbase in which the largest particles will pass a 3/4-inch sieve. If the equipment used for digging the hole cannot remove a sample that is large enough, several smaller samples should be taken from places close together, and the average of the results of all the tests should be used as if a single sample were tested.

Reducing Size of Composite Sample

10. When mechanically operated sieves of large size are used, it is usually best to pass the whole composite sample through the sieves instead of using only the portion suggested for the test. If it is not practical to use the whole composite sample, the amount to be used for the test must be separated from the rest by some method such as quartering* or riffling*.

When a composite sample contains both large particles and dust or very fine particles, it is best to use the quartering method. The material should be dampened, mixed thoroughly, and formed into a round pile on a flat base. Then the pile should be cut into four parts, or quarters, with a trowel, just as a pie would be cut with a knife. While the cuts are being made, the quarters should be pulled apart with the trowel, so that small clean spaces are left on the base between the quarters. Two diagonally opposite quarters are taken away and are not included in the test sample. The other two quarters are mixed together, and another round pile is formed. This new pile is quartered, and the steps are repeated until the right amount of material is left. All the material in the last two quarters should be used for the test. The size of the test sample should not be adjusted to get an even weight, such as 1 pound.

Test samples of aggregates and some other materials can also be obtained from composite samples with a riffle. This is a hopper with a row of small chutes in the bottom. The chutes are so arranged that when material is poured into the top of the hopper from a suitable holder, half the chutes throw material out of the hopper to one side while the other chutes throw material to the other side. The material falling out of the hopper is caught in two pans, one on each side of the riffle. The material from one of the pans is dumped out and set aside, but is not included in the test sample. The material from the other pan is returned to the pouring holder. The two empty pans are then put back under the riffle, and the material from the holder is poured into the hopper again. The steps are repeated enough times to get a sample of such size that all the material in it can be used for the test.

A riffle called a "hot sample splitter" can be used to get a test sample from a composite sample of hot mix. This kind of riffle is made by welding together pieces of 1/8-inch sheet metal. It is warmed before being used so that the asphalt won't stick to it.

When a riffle is not at hand, test samples of some aggregates, such as fine gravel, can be obtained from composite samples by using square pans with high sides. Two pans are set side by side in contact, and the sample is poured into them from a suitable holder so that the center of the stream hits the two touching sides. The material from one pan is dumped out and is not included in the test sample. The material from the other pan is again returned to the pouring holder and is then poured back into the two pans, as when a riffle is used.

Still another way, called the "thief" method, can be used to reduce the size of a composite sample of a material such as damp sand. The material in the composite sample is mixed, and a small amount of water is added, if necessary,

to dampen it. It then is formed into a pile, and the pile is flattened with a suitable tool, such as a large trowel. The test sample is obtained by combining a number of small portions taken from different points on the surface of the flattened pile with the point of the trowel.

Calculation of Percent

11. In many cases, a test result must be reported as a percent. So some multiplying or dividing of numbers is required. The calculations can take a lot of time if the work is done by applying the usual methods of arithmetic. However, much time can be saved by using a slide rule. A simple type of slide rule, with "C" and "D" scales only, is cheap and it is easy to learn how to use such a rule. The results that can be obtained by using a slide rule for doing the arithmetic are accurate enough for most tests. The answer found by a slide rule is usually correct to the first three figures, and these are the only ones that are significant or have real meaning in a test.

Many of the answers found by the usual methods are carried out too far, and the last figures really have no meaning. For instance, a gradation test may be made on a sample of sand weighing 517 grams (there are 454 grams in a pound), and the part of the sample held on each sieve may be weighed on a scale to the nearest gram.

The total weight of the sample that passes any sieve can be found by adding together the weights of material held on all the sieves with smaller openings and in the bottom pan. The percent of the sample passing any sieve is then found by dividing the weight passing this sieve by the weight of the whole sample, and multiplying the result by 100. For instance, if 109 grams of a 517-gram sample passes the No. 50 sieve, the percent passing the No. 50 sieve is

$$\frac{109}{517} \times 100 = 21.08$$

This result should be rounded off to the nearest tenth of a percent. So the answer that should be reported is 21.1 percent.

When a percent is to be rounded off, the method is as follows: If the first figure to be dropped is 0, 1, 2, 3, or 4, the part of the number ahead of that figure is used as the correct percent. For instance, if the computed percent is 31.54, the result should be reported as 31.5 percent. If the first figure to be dropped is 5, 6, 7, 8, or 9, the figure just ahead of the dropped part should be increased by 1. Thus, if the computed percent is 44.75, the answer should be reported as 44.8 percent.

Test results should be reported as directed in the Standard Procedure. There is no use in putting down more figures than are required. The extra figures do not mean anything, and their use may lead to the belief that the test was more precise* than it really was. Writing down a long string of numbers does not make a test result more accurate or of more benefit.

Ways of Controlling Quality of Materials

12. The Department controls the sampling and testing of each material in one of the following five ways:

1. An agent of the Department Laboratory samples the material at the source, and the sample is tested either at the source or at the Laboratory. If the test results are satisfactory, the District Engineer is then informed that the material met the requirements of the Specifications at the time of shipment.

2. The material is sampled in the Field (on the job), and the sample is sent to the Laboratory for testing.

3. The material is inspected or sampled and tested on the job.

4. The material is sampled and tested on the job, but a part of the same sample is sent to the Department Laboratory for check testing.

5. The material is not sampled or tested, but is accepted on the basis of a certification or guarantee furnished by the manufacturer or supplier.

The Inspector-in-Charge must know which method of control is to be used for each material, so that he will take the right steps when material arrives on the job. Using the correct method of control will thus speed up the approval or rejection of material and will thus avoid delays in construction.

Handling Rejected Material

13. No material should be used in the construction unless it has been approved. When a lot of material is tested on the job and the test results are not entirely satisfactory, all the material in the lot should be set aside, and a representative sample should be immediately taken from the lot and sent to the Laboratory for a confirmation of the test results. This sample should be shipped by parcel post, special delivery. The copy of Form 447, Sample Identification, that is enclosed with or attached to the sample must be marked "Rush", and the reason for the possible rejection must be noted on the Form. The Contractor must either wait to unload the doubtful material or store it separately until it has been accepted or rejected. The results of the tests made at the Laboratory will be given to the Inspector by the District Office.

If Laboratory tests show that a lot of material does not meet the requirements of the Specifications, the entire lot must be removed from the job. Also, the Inspector must fill out and send to the Laboratory Form 455 on which he describes what was done with the rejected material. This Form must be cleared through the District Engineer and approved by him, because he should be fully informed whenever material is rejected.

The first three items under "Remarks" on Form 455 will cover 90 percent of the cases relating to rejected material. Item No. 4 covers special cases of rejected material. If it applies, it is filled in by someone other than the Inspector. Since rejected material must never be used on the job, the Inspec-

tor-in-Charge must be notified immediately when any material is rejected. He can then guard against its use in the construction.

When a check sample of rejected material is required, it is obtained by the District Materials Engineer or under his supervision. A notation referring to the Laboratory number of the rejected material must be included on the copy of Form 447, Sample Identification, sent with the check sample.

Kinds of Materials Sampled at Source

14. Some materials have already been sampled and tested before they arrive on the job. They have been approved by the Department at the plants at which they are manufactured, and the Specifications required that they be identified by a tag, seal, or stamp before being shipped. A few materials are accepted by the Department on the basis of the producer's certification.

The following materials are usually approved at the plants at which they are manufactured:

1. Reinforced or plain cement concrete pipe and metal plate pipe.
2. Bituminous material.
3. Gasoline, naphtha, and lubricating oil.
4. Paints, varnishes, oils, and all other painting items.
5. Portland cement.
6. Prestressed concrete members.
7. Structural steel, including shells for piling.
8. Steel reinforcement for bridges.
9. Right-of-Way fences and guard fences, and their parts.
10. Sod, seed, fertilizer, lime, and mulch.
11. Vitrified brick.

General Duties of Inspector

15. When a lot of material from tested and approved stock is shipped to the job from the plant at which it was manufactured, the District Office gets word of the shipment. The District Office then notifies the Inspector-in-Charge that the material has been approved by the Department, and sends him a form, certificate, or directive relating to the shipment. He must keep this on file in the Field Office.

The fact that a certain lot of material has been approved before being shipped from the manufacturing plant does not relieve the Inspector of his most important duty. He must make sure that all material placed in the construction is exactly as shown on the Plans and as called for in the Specifications.

When an approved lot of material arrives on the job, the Inspector must check it completely. If it is not tagged, sealed, or stamped, it must be set aside until written approval of its use is obtained from the District Engineer. If the Inspector finds that material has been damaged in shipment, it must be either rejected or set aside until written approval of its use is obtained. If there is any doubt about the quality of material, the Inspector must take a sample and ship it to the Laboratory.

If material that is normally approved at the manufacturer's plant is received without notification of acceptance, or if the name of the manufacturer is not on the Department's approved list, or if visual inspection* indicates that the material may not be entirely satisfactory, the Inspector-in-Charge should do the following things:

1. Notify the District Materials Engineer or the Soils Engineer; the proper person depends on the type of material.

2. Obtain samples of the material, if directed to do so.

3. Inform the Contractor that the material cannot be used until he gets written approval from the District Engineer.

<u>Inspection of Pipe</u>

16. The Laboratory makes periodic inspections at plants manufacturing reinforced concrete pipe or plain cement concrete pipe. The manufacturer submits to the Laboratory a certification (Department Form 491) stating that the pipe was manufactured in accordance with Department Standards and Specifications. Upon receipt of Form 491 from the manufacturer, the Laboratory puts the required information on the job project sheet. Copies of the Form are then sent to the District Engineer.

Samples of galvanized corrugated sheet metal to be used in pipes are cut from pieces of the material by Laboratory Inspectors at the plant at which the material is manufactured. The samples may be tested at the manufacturing plant, at the fabricating plant*, or at the Department Laboratory. When the sheet metal is approved and the pipe is shipped to the Department project, the fabricator submits to the Laboratory a certification (Department Form 4116) stating that the pipe was manufactured in accordance with Department Standards and Specifications from previously tested and approved stock. The method of processing Form 4116 by the Laboratory is similar to that for Form 491.

Even though some pipe materials are accepted on the basis of the manufacturer's certification, it is still necessary for the project Inspector to inspect pipe visually* and to take samples from the project if the pipes do not look right or if there is any doubt about the quality of the material.

The Specifications for pipe are very definite and clear. A piece of pipe will not be accepted in the field unless it meets the following requirements:

a. Certain information must have been either stamped or stenciled on each piece of cast-iron, concrete, or metal pipe. Such marking is not called for on clay pipe.
b. The length, inside diameter, wall thickness or gage, and size and spacing of corrugations and rivets, as found by field measurement, must be correct.
c. The workmanship that went into each piece must be acceptable. Defects* to be looked for in concrete pipe are cracks, spalls, or poor texture. Those in cast-iron pipe are roughness, cracks, blisters,

rust or incomplete coating of coal-tar pitch varnish on the inside or outside surface. Those in corrugated or plate metal pipe are damage to the spelter* coating or the asphalt coating or dents or bends in the metal; Those in clay pipe are cracks, warps, or surface roughness.

If, for any reason, a sample of corrugated metal pipe* is to be sent to the Laboratory, a piece long enough to include at least two corrugations should be cut from a section of each size of pipe. This cutting is usually done by the Contractor with an acetylene torch*. The Inspector should see to it that the cutting is done without damaging the spelter coating beyond the cut area. If the pipe is coated with asphalt, a piece long enough to include four corrugations should be cut out. The extra length is needed to make sure that the Laboratory gets a piece on which the asphalt was not damaged by heating. A sample of pipe of any other material should be taken in accordance with instructions given to the Inspector-in-Charge by the District Materials Engineer.

Inspection of Bituminous Material

17. Asphalt cements*, coal-tar cements*, cut-backs*, emulsions*, road oils*, and other similar bituminous materials* are normally shipped in railroad tank cars or tank trucks.

If sent by tank car, the dome* of each car will be sealed with a Department seal*. A Material Acceptance Card, Form 4162, is attached to the car at the refinery*. This form shows the seal number*, the class of material, the distributor, and other information. Sometimes this Form comes off the car during transit. If the dome is sealed, the material can be accepted. If the dome is not sealed, the Laboratory must test the material before it can be unloaded. Either Form 4162 or Form 431 must be delivered with any bituminous material shipped by tank truck. A shipment that does not have either one of these forms cannot be accepted.

If, for any reason, a sample of bituminous material must be taken and sent to the Laboratory for test, the reason for testing must be noted on the attached copy of Form 447, Sample Identification. Solid material collected from a tank car or truck must be heated until it becomes liquid and then mixed thoroughly before it is sampled.

A sample of bituminous material is gotten by lowering a weighted container, or by pushing a can or bottle, all the way down through the material and then pulling it back up through the material. This method must be used so that some material is gotten at each level in the tank. The opening in the container, can, or bottle should be not more than 2 inches in diameter. If the opening were larger, the container, can, or bottle would be filled before it reached the bottom of the tank.

The shipping container must be closed tightly so that none of the material will leak out. A good way to check its tightness is to turn the container upside down after it has been closed.

A drum or barrel containing bituminous material will have either the Inspection Notice, Form 470, attached to it or the words "P.D.H. Inspected" stamped or stenciled on its head or side. The Laboratory Inspector's initials or name will also be shown.

When solid or partly-solid material in a drum or barrel is to be sampled, the sample should not be taken from the surface, but from a point at least 6 inches below the surface and at least 3 inches from the sides. If the material is hard enough to be broken into small pieces, a clean hatchet should be used. If the material is too soft to be broken, the sample should be cut out with a stiff sharp blade that has been warmed.

A number of other bituminous items, such as brick filler, and joint-sealing or waterproofing material, do not have to be sampled unless a sample is asked for by the Laboratory. When no sample is needed, Form 470 will be attached to the container in which the material is delivered to the job. If a sample is wanted, the Laboratory will send complete sampling instructions.

Samples of compounds containing rubber, for sealing joints or cracks, should be taken from each shipment as follows: (a) 1 gallon of liquid material or (b) 10 pounds of solid material collected without heating.

Inspection of Other Liquid Materials

18. Gasoline, naphtha, or lubricating oil can be accepted if the tank or drum containing it is sealed or stamped by the Laboratory, or if it is accompanied by Form 470. If a sample is needed, 1 quart of the liquid should be drawn off into a screw-top can and shipped to the Laboratory. It should be packed and identified by a Red Seal*, in accordance with Interstate Commerce Commission regulations.

Paints, varnish, or any other painting item can be accepted if it is accompanied by Form 470. If the quality of the material is in doubt, a 1-quart sample should be drawn off and shipped to the Laboratory. Before being sampled, the material must be mixed thoroughly until it is completely uniform. This mixing can be done by either rolling the drum or stirring the material with a paddle.

Inspection of Portland Cement

19. When portland cement has been accepted at the mill and need not be sampled on delivery at the job, any shipment of the cement in bags or bulk must be accompanied by a Cement Acceptance Report, Form 4111. If only a small number of bags are shipped, each bag will be stamped with the Department seal.

Whenever cement is to be sampled on delivery at the job and tested, as after winter storage, it must be held on the job until its use is approved. The total time to be allowed includes 8 days for Laboratory testing in addition to the time needed to ship the sample to the Laboratory and that time needed for the results to get back to the Field Office.

Samples of bagged cement must be taken from stock that is known to be of the same brand and age. In the case of a large shipment, one sample must be taken for each carload, or about 600 bags, of cement. Each sample should weigh from 8 to 10 pounds, and be made up of cement taken from 8 to 10 bags chosen from different places in the stock. If there is less than a carload, a composite sample must be made up of material taken from at least 5 bags. The sample and the stock it represents must be marked with the same letter of the alphabet, in order that the stock represented by the sample can be identified easily in case this cement is rejected.

It should never be necessary to rip open a bag to get a sample of cement. The simplest way to collect a sample of cement from a bag is to use thief like that described in Section 7. While the thief is being emptied into the sample container, the air-escape hole should be left open. In case the cement has set and caked, so that it cannot be sampled by use of a thief, the lot should be rejected.

Bulk cement is sampled by opening the discharge gate of the bin and slowly drawing out about 2 percent of the stored cement. Small amounts should be taken from the stream of cement at different times until a sample weighing 8 to 10 pounds has been collected.

Each composite sample of cement must be placed in a double-walled paper bag and then in a canvas bag issued by the Department for this purpose.

Inspection of Prestressed Concrete Members

20. All approved prestressed concrete members* will be stamped with the Department inspection stamp when they arrive on the project. In addition, one copy of Form 4216, Notice of Shipment of Precast Prestressed Concrete Bridge Deck Beams, will be forwarded from the District Office. As soon as a shipment is received on the job, each member should be inspected for spalls*, cracks*, and any other surface defects. The dimensions* of the member and the spacing* of the shear connectors* should also be checked against those shown on the Contract Drawings. Any error or defect should be brought at once to the attention of the Assistant District Construction Engineer.

Inspection of Structural and Reinforcing Steel

21. When the tests on a shipment of structural steel are made at a private testing laboratory, three copies of the laboratory's report are sent to the Chief Bridge Engineer. He then gives the District Office one copy of this report and also the pay weight of the steel in the shipment. In turn, the District Office gives the Inspector-in-Charge all the required information about the material in the shipment. In most instances, the total pay weight is shown for the following: fabricated structural steel*, plain structural steel* in a bridge, steel-beam bridge flooring, steel for shells of cast-in-place concrete piles*, steel pipe piles*, and steel beam piles*.

Before steel is used on the job, the material should be checked against the requirements shown on the Plans. Steel beams should be checked for straightness and for the amount of camber*, if any, called for on the Plans. The

condition of steel anchor bars* on expansion joints* and other small parts should be checked. Such bars are often bent or twisted, and sometimes broken off, during shipment.

A shipment of approved steel reinforcing bars* for a concrete structure must be accompanied by an Acceptance Notice, Form 489. If Form 489 is not received, samples of the material must be taken as directed by the Bridge Engineer. Two pieces, 24-inches long, of each size of bar in the shipment are usually chosen as samples.

Inspection of Guard-Fence

22. The items included in guard fence* are wire rope*, wire fabric*, plate spring brackets*, bolts, offset castings*, posts, splices, end connections, and miscellaneous fittings. If a shipment of material for guard fence is received on the job without the Inspector-in-Charge having been notified, or if the material does not appear entirely satisfactory, a sample from the shipment must be sent to the laboratory. The kind of sample depends on the type of guard fence, as shown in the following list:

> Two pieces of wire rope of each size, 30 inches long.
>
> One piece of wire fence, or plate, 36 inches long.
>
> One spring bracket, bolt, offset casting, steel post, splice, end connection, or miscellaneous fitting.

Wooden posts are to be inspected as described in the Specifications. Any material not meeting the requirements must be rejected and removed from the job.

Inspection of Sod, Seed, Fertilizer, Lime, and Mulch

23. Sod will have been inspected at the source to determine if it has the proper amounts of different types of grasses. The Inspector on the job should make sure that sod is between 1 and 1-1/2 inches thick and in lengths called for by the Specifications, and that it is placed not more than 48 hours after being cut.

Seed, fertilizer, lime*, or mulch usually need not be sampled. If samples are wanted by the Laboratory, the Inspector will be given full instructions for taking them. Each bag of seed must have inside it a tag stamped, signed, and dated by the Department. Seed over 8 months old is not to be used.

Inspection of Vitrified Brick

24. Vitrified brick* is usually tested and approved at the source, and a shipment can be used whenever the Material Inspection Notice, Form 489, is received with it. However, bricks that are chipped or cracked, or otherwise unfit for laying, must be rejected and removed from the job.

Sometimes, as when the shipment is small, vitrified brick must be sampled on the job. A sample should consist of 12 bricks from each truck or railroad

car. The bricks should be taken from as many different places in the load as possible, and not from just the top or outer layers. Where the colors of the bricks show different amounts of burning*, the sample should represent the different shades (light, medium, and dark). The sample should be prepared for shipping by wrapping each brick in a paper separately and packing all twelve securely in a box.

Kinds of Materials Sampled in Field and Tested at Laboratory

25. Many materials used in construction should be sampled in the field at the source or when they arrive on the job, and the samples should be sent to the Laboratory for testing. The materials included in this class are the following:

1. Coarse and fine aggregates for surface courses* or base courses*.
2. Sand for cement-sand bed*, filler*, and similar uses.
3. Soil for subgrade* or embankment* material.
4. Steel reinforcement* for concrete pavement.
5. Steel elements in longitudinal joints*.
6. Material for filling and sealing joints and cracks.
7. Waterproofing cement*.
8. Waterproofing fabric*.
9. Compound* for curing portland cement concrete.
10. Water for use in portland cement concrete.
11. Calcium chloride*.
12. Copper flashing*.
13. Concrete blocks*.
14. Hydrated lime*.

The first three materials included here are found in nature, and are sampled at the source. A source of natural material must be approved by the District Materials Engineer before the material is used in the construction. Each of the other products is manufactured.[1] The producer of a manufactured product may have been approved by the Department, and the Inspector-in-Charge should have a list of all approved producers. Material made by each producer whose name is on the approved list is checked from time to time by the Laboratory. As long as his product is meeting all the chemical and physical requirements of the Specifications, his name is kept on the list. His name on the product is then considered a guarantee of its quality. However, a shipment of material furnished by an approved producer or obtained from an approved source is not actually approved before it arrives on the job. It is the duty and responsibility of the Inspector-in-Charge to make sure that each shipment is sampled in the field and that the sample is tested and the shipment is approved before any of the material in the shipment is used.

Identification and Preliminary Inspection of Material

26. As soon as a shipment of material arrives on the job, the Inspector should do the following things:

1. Identify* the producer of the material.
2. Inspect the material for visible defects or faulty workmanship.
3. Sample the material in accordance with the Standard Procedure.

[1]Since water from city mains has been processed, or treated with chemicals, it is listed as a manufactured material.

4. Properly package the sample for shipment to the Laboratory.
5. Make certain that the Sample Identification, Form 447, is filled in completely (preferably in ink) and is enclosed in or attached to the package.
6. Inform the Contractor when the results may be expected from the Laboratory.

The location of a commercial quarry*, ledge*, sand or gravel bank*, or other deposit of natural material can be shown on Form 447 either by giving the nearest post office or railroad station, the township, the county and the State if it is not Pennsylvania; or by giving the highway route number, the station on the route or the distance and direction from the nearest station, the township, and the county.

Form 447 is usually placed in a tag envelope, Form 7118, which is put inside the sample container. However, if the sample may damage the Form, it should be attached to the outside of the container.

Packing and Shipping Samples

27. Samples of most materials are shipped to the Laboratory in specified types of containers, as described below. Samples of some materials, such as dowel bars*, hook-bolt dowels*, pipe, wire rope, and posts, are shipped unpacked, and Form 447 is securely attached to the sample.

Liquid materials, such as gasoline*, naphtha*, fuel oil*, and paint, and other materials which are in a liquid form when sampled and then harden, such as some bituminous materials, are shipped in friction-top or screw-top cans, glass jars, or airtight glass containers. As soon as a sample has been put into the container, the lid must be put on as tightly as possible and the container turned over completely to check for any leaks. The container must be packed in a sturdy box. No container should be placed loosely in a box. To prevent jarring of the container, especially if it is of glass, it should be held in place snugly with shredded or crumpled newspaper, foam rubber, or any other suitable material that may be available.

Samples of solid materials in the form of small particles, such as coarse and fine aggregates, cement, lime, and soils, are placed and shipped in Department canvas bags. Each bag should be checked for holes or weak spots in the fabric, and should be handled so that it will not tear. A bag containing fine material, such as cement or lime, must be wrapped in paper.

Bricks should be packed by wrapping each one in paper separately and putting them in a sturdy wooden box.

REMEMBER

If a sample is not fit for useful testing when it reaches the Laboratory or is lost during shipment because it was carelessly packaged, valuable time is wasted. The use of the material by the Contractor will be delayed until a new sample is taken, packaged, shipped, tested, and approved.

A dry sample weighing 15 pounds or more must be shipped by express. A sample of gasoline, fuel oil, or any flammable material, regardless of its weight, must be shipped by express and clearly marked "Liquid", "Fragile", or "Flammable", or with more than one of these words, if necessary.

Sampling Coarse and Fine Aggregates

28. A composite sample* of fine or coarse aggregate should weigh between 25 and 75 pounds.

If the material is to be obtained from a recently worked deposit, several composite samples should be taken from different places along the face of the bank. Each such sample should be made up of material having the same appearance. The nature of the material changes from one layer to the next, and a sample should be taken for each layer. Material beyond the face* of the bank of a recently worked deposit, or material from a new source, has to be gotten from test holes. These holes may be either made with an auger or dug. When samples are being taken from a test hole, the fresh material has to be watched closely for any changes in appearance, and a separate sample should be taken for each type. In every case, the Inspector should keep a record to show the area represented by the sample, or the location of the test hole and the depth below the surface.

Sources of coarse aggregate are commercial quarries, unworked ledges, deposits of boulders, stone fences, and other deposits of field stone. A composite sample should weigh from 50 to 80 pounds, and each stone in it should weigh between 8 and 10 pounds. All major types of stone in the source should be represented, and the location and depth of each type should be recorded. Stones from open sources must be unweathered and sound. Instructions for taking samples of stone from a commercial quarry will be given by the Laboratory.

Form 447 and the Report of Material Investigation, Form 430, must be sent to the Laboratory along with the sample. An estimate of the amount of material, in cubic yards, represented by the sample must be shown on both Forms.

Sampling Other Natural Materials

29. A sample of sand to be used for a cement-sand bed, filler or other similar purpose is required from the first shipment of the sand received on the work and also from each shipment after that if the sand appears different or if the quality is doubtful. The method of sampling is the same as that described for fine aggregate.

Samples of soil in a subgrade are taken for mechanical analysis* and the moisture-density relationship*. Soil from a borrow pit for use in an embankment must be tested also for other qualities. Soil samples should be taken as directed and as described in Department Bulletin 39.

Sampling Pavement Materials

30. Every shipment of steel reinforcement for a concrete pavement must be sampled. A sample of welded wire mesh* should be at least 2 feet square, and should include all sizes of longitudinal* and transverse* wires. A sample of bar reinforcement should consist of two pieces of each size of bar, each piece being about 24 inches long.

Each shipment of materials for the longitudinal joint* in a concrete pavement must be sampled. A sample should be made up of either two dowel bars* or a piece of dowel shield* 24 inches long, and one complete hook-bolt dowel* consisting of the sections with the 5-inch leg and the 2-inch leg and the sleeve.

A sample from each shipment of premolded expansion-joint material* must extend over the full depth of the strip of material and be at least 12 inches long.

A shipment of material of Type J-1 used for sealing joints and crakcs in concrete pavement must be sampled if the shipment is received without the Inspection Notice, Form 470. A sample should consist of 1-gallon of the material.

Rubber compounds* used for sealing joints and cracks must be sampled, a sample being taken from each shipment. If the material is liquid, the sample size is 1-gallon; if the material is solid, the sample size is 10 pounds.

Sampling Waterproofing and Curing Materials

31. If a shipment of waterproofing cement* arrives on the job without Form 470, a 2-pound or 1-quart sample must be taken for tests. A sample taken from each shipment of waterproofing fabric* should be at least 12 inches square.

A 1-quart sample should be taken from each shipment of compound for curing concrete. It is important that the material in the drum be mixed thoroughly before the sample is taken, because some of the ingredients tend to settle out during storage. Unless the drum has an agitator, the contents should be mixed by turning the drum end-for-end several times and rolling it at least 100 feet.

Sampling Water and Calcium Chloride

32. A 1-quart sample must be taken from each source of water to be used in concrete and for wetting aggregate in stockpiles.

A 1-pound sample of calcium chloride must be taken from each car. The sample should be placed in an airtight glass container, to avoid absorption of water from the air.

Sampling Other Materials

33. A sample 12 inches square is to be taken from each shipment of copper flashing*.

Bricks that are chipped or cracked or otherwise unfit for laying should be rejected immediately.

Each shipment of hydrated lime* to be used for structural purposes* must be sampled. Each composite sample* should weigh about 5 pounds and should be made up of portions taken from at least five bags in the shipment.

Summary of Field Sampling of Materials

34. The information in Table III covers routine details of sampling materials in the field. Exceptions are noted. Regulations governing preliminary sampling of materials for construction work are described in detail in Department Specifications.

Samples are to be sent to Pennsylvania Department of Highways Testing Laboratory, 1118 State Street, Harrisburg, Pennsylvania.

TABLE III - Summary of Field Sampling of Materials

Kind of Material	When Sampled	Size of Sample	Type of Containe
Aggregate, Coarse (Stone, gravel, or slag)	First shipment,* and others as directed.	#1B -- 20-30 lb #2 -- 25-40 lb #2A -- 20-50 lb #2B -- 20-50 lb #3A -- 50-75 lb #4 -- 100-125 lb All slag 70 lb	Strong canvas ba
Aggregate, Fine (Sand, screenings)	First shipment, and then each 1,000 tons	7 to 10 pounds	Canvas bag
Bituminous Concrete:			
a) Cold Mixture . .	Each 1000 tons**	10 pounds	1-gallon frictio top can
b) Hot Mixture . .	One per week**	10 pounds	Clean Carton
Bituminous Materials:			
a) Asphaltic emulsions with water	Each car**	1 gallon	Air-tight glass container
b) Tars and asphalts, liquid	Each car**	1 quart	Screw-top can

TABLE III (Continued)

Kind of Material	When Sampled	Size of Sample	Type of Container
c) Tars and asphalts, solid	Each shipment**	1 quart	Friction-top can
Brick, Masonry	Each shipment**	10 bricks	Wood container
Brick, Vitrified	Each car**	12 bricks	Wood container
Calcium chloride	Each car	1 pound	Glass jar
Cement	Each car**	8 to 10 pounds	Canvas bag wrapped in paper
Copper flashing	Each shipment	1 piece, 12 inches square	
Curing compound	Each shipment	1 quart	Screw-top can
Dowels for longitudinal joint, Hook-bolt	Each shipment	1 complete unit	
Dowel bars for longitudinal joint	Each shipment	2 bars	
Gasoline	Each shipment	1 quart	Screw-top can
Joint filler:			
a) Bituminous	Each shipment	1/2 gallon	1-gallon friction-top can
b) Hot rubber compound	Each shipment	10 pounds	Heavy paper wrapping
c) Premolded	Each shipment	5 pounds	Canvas bag wrapped in paper
Naphtha	Each shipment**	1 quart	Screw-top can
Oils, Lubricating	Each shipment**	1 quart	Screw-top can
Paint, Ready-mixed	Each shipment**	1 quart	Friction-top can

TABLE III (Continued)

Kind of Material	When Sampled	Size of Sample	Type of Container
Pipe, Bituminized fiber	Each shipment**	1 section	
Pipe, Plain or asphalt coated corrugated metal	Each shipment**	2 corrugations wide, full periphery	
Pipe, Vitrified clay	Each shipment**	1 section	
Reinforcement, Bar	Each shipment	2 pieces of each diameter, 2 feet long	
Reinforcement, welded wire	Each shipment	Section not less than 2 feet square including each size of wire	
Rubber asphalt	Each shipment	1 quart	Friction-top can
Sheet asphalt for wearing course . .	Daily**	1/4 pound	Tin box
Soils	As directed*	*	Canvas bag
Subbase aggregate	As directed*	20 to 75 pounds	Canvas bag
Turpentine	Each shipment**	1 quart	Screw-top can
Water	From each source	1 quart	Glass jar
Wire rope	Each shipment**	2 pieces of each diameter, 30 inches long	

*See instructions **Unless otherwise instructed

A sample of masonry bricks taken from either a truck or a railroad car should consist of 10 bricks. If all the bricks have about the same color, those in the sample may be picked at random. Where the colors indicate different amounts of burning, the Inspector should estimate the percentage of each shade in the

shipment, and should use these percentages in deciding how many bricks of a certain shade should be included in the sample.

Materials Inspected or Sampled and Tested on the Job

35. The materials which are usually accepted or rejected on the basis of field inspection alone are the following:

Material approved at its source
Run-of-bank gravel
Mine waste
Red dog*
Lumber
Wooden guard-fence posts or guard posts
Nails
Assemblies for transverse joints in concrete pavement
Corrugated metal plates for culverts
Bridge rail, drainage castings, and steel for covered gutters
Cribbing members of steel or reinforced concrete
Covering material for curing concrete

When material has been approved at its source, each shipment should be inspected as soon as it arrives on the job to make sure that it looks all right. Run-of-bank gravel or mine waste need not be sampled or tested when it arrives on the job unless it is to be used in a subbase course.

Lumber is inspected on its arrival at the project by a representative of the District Office. If a carload shipment is received from a source outside Pennsylvania, an affidavit* in regard to the kind and character of the material is required from a Lumber Association Inspector. Wooden posts may or may not have been inspected at the source. In either case, each post must be inspected on the job before it is put in place, and any post that is rejected should be marked and removed from the project.

Premolded filler* in a transverse expansion joint* must be sampled, and the sample sent to the Laboratory for tests. The metal parts of an assembly for a transverse joint must be checked on the job against the dimensions and other requirements shown on the Standard Drawings. If any unit does not meet all the requirements in every detail, a sample must be sent to the Laboratory. The sample should be an actual part of the unit which is long enough to include two dowels* with nose caps*.

Such items as corrugated metal plates for culverts, bridge rail, drainage castings, steel for covered gutters, and cribbing members* should be inspected on the project for dimensions, workmanship, and other requirements described on the Plans and Standard Drawings and in the Specifications. If any item does not meet all requirements, the Assistant District Engineer must be notified at once.

The material used for covering concrete during the curing process is not a construction material in the true sense. However, the strength and the lasting quality of concrete depends to a great extent on the tightness of the paper covering used in the curing process. The Specifications describe the requirements

for covering material. If covering material has holes in it, no matter how small they may be, it should be rejected.

Materials Requiring Check Tests at Laboratory

36. Some materials are usually tested for acceptance at a field laboratory, but a part of the same sample must be sent to the Department Laboratory for check testing. The materials included in this class are bituminous concrete* mixtures, asphalt cement* of Class A-1 for a bituminous surface course* of Type JA-1, and fine and coarse aggregates.

Materials Accepted on Basis of Manufacturer's Certification

37. When structural steel is not tested under a contract between the Department and a private testing laboratory, miscellaneous structural steel can be accepted on the basis of a certified report* from the manufacturer. Two certified copies of all mill reports covering the chemical* and physical tests* of such steel must be furnished by the Contractor. One copy of the mill report is sent to the Laboratory, together with a letter giving the route, county, and Contractor or the number of the purchase order to which it applies. The Laboratory then compares the mill report with the Specifications in either Form 408 or Form 409, to find out if the steel complies with the Specification of the American Society for Testing Materials, and notifies the District Office whether or not the steel can be used.

Importance of Proportioning Plant for Concrete

38. A new man entering the service of the Department in construction work is sometimes assigned to a material plant, in order that he may learn the requirements of good concrete construction, which has its beginning in the raw materials.

The Specifications and Supplements, together with the Special Provisions of the Contract and the instructions and information in this Construction Manual, clearly describe procedures for the control of materials. An Inspector at a material plant should become thoroughly familiar with all the requirements of the Specifications in regard to the raw materials for concrete and with the rules and procedures that have been set up by the Department to control the proportioning of the materials. He should enforce these requirements at all times. He does not have the authority to waive (not fully enforce) any of the provisions of the Specifications or to change the proportions of the concrete mix as set up by the Contractor or his authorized representative and approved by the District Engineer. If there is a question in the Inspector's mind at any time about the conduct of any phase of the work to which he is assigned, he should seek the advice of the Inspector-in-Charge, who in turn may get advice from the District Construction Engineer.

The Inspector assigned to a proportioning plant, where materials for concrete are tested and proportioned, is responsible for obtaining concrete of good quality. Unless the work at a proportioning plant is inspected in an honest, intelligent, and efficient manner, the Department will get concrete of inferior quality in which structural defects are liable to develop.

In addition to being one of the most important factors in obtaining high quality concrete, the operation of the proportioning plant is usually the key to the Contractor's progress. Any delay at this plant is directly reflected in the amount of concrete the Contractor is able to place in a given time. As long as the Contractor is meeting all requirements of the Plans and Specifications the Department representatives should give him their full cooperation by carrying out their duties at the plant so as to avoid delays.

Where a proportioning plant is set up by the Contractor only for the use of the project, the District Construction Engineer, with the Inspector-in-Charge and the Materials Inspector, will check the plant some time before it is put into operation, to see that the equipment which the Contractor intends to use meets Department requirements. This check should include necessary tests of the equipment. If any adjustments are needed, they can be made without delaying work on the project.

If the Contractor intends to use ready-mixed concrete obtained from the plant of a commercial producer, the plant must be listed as approved in Bulletin 42, entitled List of Commercial Producers of Ready-Mixed Concrete, or the plant must be approved by the District Materials Engineer, Construction Engineer, and Maintenance Engineer.

Duties of Plant Inspector

39. The first duty of an Inspector at a proportioning plant is to determine whether or not the materials being received are coming from approved sources. The Laboratory has published the necessary information about aggregates in Bulletins 13 and 14. In case a shipment of material is not properly identified, the Inspector should notify the Project Engineer, who in turn notifies the Assistant District Construction Engineer or the District Materials Engineer, who can check the source of supply.

If a shipment of material must be sampled and tested, the Inspector should cooperate with the Contractor by collecting the samples as soon as the shipment is received and sending the samples to the Laboratory or making his field tests without delay. The Contractor can at once dispose of material which does not meet the requirements of the Specifications, and arrange to get other material to replace it; or he can set aside material which must be held while check tests are being made at the Laboratory.

In addition to taking samples, making tests, and preparing reports, the Inspector at a proportioning plant is responsible for the following requirements:

(a) The scales are tested for accuracy and checked for balance several times each day.
(b) The batch weights of the aggregates as shown on the Batcher-Mixer Slips, Form 4220, are posted in full view at the scales, and these amounts are weighed out accurately.
(c) The weighing hopper is entirely empty after the materials have been dumped into the truck. (This supervision is particularly important where bulk cement is being used; very often cement sticks to the sides and corners of the hopper, and there is a loss of this material in each batch).

(d) The required number of bags of cement or the proper weight of bulk cement is placed on each truck.
(e) The temperature of the cement in each car tank truck is taken before it is unloaded. (The temperature of the cement at the time of delivery to the mixer must not exceed the specified maximum).
(f) Truck partitions are tight and high enough to prevent the intermingling of aggregates; the sides and back of the truck are high enough to prevent loss of material; and the cover of the cement container is securely fastened in place.
(g) Approved bases are placed under stockpiles.
(h) Partitions between stockpiles of aggregates are strong enough and high enough to prevent intermingling of the different sizes.
(i) No mud or other foreign material gets into the stockpiles.
(j) Aggregate is stockpiled in layers not more than 4 feet thick to avoid segregation.
(k) Lumps of frozen materials are not placed in the weighing hopper or aggregate bins.
(l) The aggregates being used contain the amount of moisture shown for the last moisture determination on Form 4220. (The crane operator should not be allowed to fill the bin from two stockpiles of the same material with different moisture contents).
(m) The sources of materials are not changed without permission in writing from the District Engineer. (If permission is granted, a new Mix Computation, Form 4221, must be prepared).
(n) The Project Engineer is notified and he in turn notifies the Assistant District Construction Engineer or the District Materials Engineer if there is any radical* change in the gradation of the aggregates.
(o) Protection from the weather is provided for all materials requiring it.
(p) The top of the batcher-bin partition is at least 4 feet above the top of the bin, and the surface of the materials in the bin is never less than 2 feet below the top of this partition.
(q) The record of batches sent to the mixer is accurate and is compared with the Mixer Inspector's record each day.
(r) Samples of aggregate taken for grading analyses are representative samples.

Testing and Checking Scales

40. Before an Inspector at a proportioning plant allows any material to be sent out he must arrange to test the scales with ten 50-pound check weights, which the Contractor or Producer will furnish. Details of the method of checking the scales and recording the results on Page 21 of Form 4221 are given in Section 48 of this Chapter.

At regular intervals during the day, the Plant Inspector must check all scales for balance; that is, he must determine whether or not the indicator returns to zero after each weighing. This check for balance should be made between 6 and 12 times during working hours. If the indicator does not return to zero, then the equipment will have to be inspected to find out if materials have

stuck in the weigh hopper, if the knife edges of the fulcrum points* are clean, of if there is binding in any part of the scale. The faulty condition will have to be corrected before more batches are sent out.

The Contractor or the Plant Operator must keep the scales in good working order and adjustment. The Inspector should never try to fix or adjust any type of scale.

Batch Weights of Aggregates

41. On Page 4 of Form 4221, Concrete Mix Computation, which is furnished by the District Office, will be shown the dry weights of the various aggregates for each class of concrete specified. The Plant Inspector uses these weights and the results of the moisture determinations to compute the quantities of the various aggregates that should be weighed at the batcher.

Each day the Material Inspector must determine the percentages of surface moisture* on the coarse and fine aggregates, and must fill out the Batcher-Mixer Slip, Form 4220. The moisture content* should be determined early enough in the day to permit the completion of Form 4220 before loading of the batch trucks is started. This Form should be sent to the Mixer Inspector with one of the first batch trucks. It gives the weights of the various aggregates to be used in making up each batch, and also shows the amount of water to be added at the mixer to give the required slump. The moisture contents may also have to be determined at various times during the day, as directed by the District Materials Engineer or as weather conditions change. To avoid unnecessary loss of moisture, aggregates should not be transferred from stock-piles to bins until just before they will be used. If the moisture content of the aggregates change, a new Batcher-Mixer Slip must be sent to the Mixer Inspector, so that he can make any necessary change in the additional amount of water to be used in each batch.

Field Tests of Aggregates

42. When fine or coarse aggregate is delivered to the proportioning plant in a railroad car, the Materials Inspector must see to it that the aggregate is tested before the car is unloaded. When aggregate is shipped by truck, the newly delivered material should be kept separate from the approved material in a stockpile until it has been tested and found satisfactory. The Contractor should be told that he must notify the Plant Inspector as soon as material arrives, so that the necessary tests can be made without delaying his operations. To provide time to establish and maintain a stable* and uniform* moisture content, aggregates must be in storage at the plant at least 18 hours before they are used. All rejected material must be removed promptly from the plant site, to keep it from becoming mixed with approved material. Also, if material from a lot that has been rejected has left the plant, it must be removed from the work, and a report of its disposition sent to the District Office on Form 455.

The Material Inspector must record in his Materials Plant Book complete data on all materials received and sent out each day. This book must also show the grading of each shipment of aggregates and the results of all Laboratory tests.

For the testing of coarse aggregates, the Specifications require the Contractor to furnish an approved platform scale that can show any weight up to 200 pounds to the nearest 1/4 pound and, if required by the Engineer, a standard container having a volume of exactly 1 cubic foot. When tests are made at any place other than the Department Laboratory, the Contractor must provide any men needed to help in collecting samples and transporting them to the site of the tests, and in testing the scales.

Delay is often caused by inaccurate field testing of aggregates. If the results of a field test indicate that material does not meet the requirements of the Specifications, the Materials Inspector should immediately get another representative sample and run a check test on it. If this second sample fails to pass the test, the Inspector-in-Charge should be notified promptly. Also, the Contractor's representative should be informed at once that the material is being held, because of its failure to meet the field test, until a sample of it is submitted to the Laboratory and either the rejection is confirmed or the material is accepted.

In case a lot of material is approved on the basis of field tests on a part of a sample but the results of Laboratory tests on another part of the same sample do not agree with the results of the field tests, a check sample of the material must be taken by the District Materials Engineer or under his direction. Confirmation by the Laboratory of the rejection often depends mainly on the care with which a sample was selected so that it would be truly representative of the material, and also on the care taken in making the field tests. It is embarrassing to the Department, and costly to the Contractor, to have material finally accepted by the Laboratory after it has been rejected and held by the Plant Inspector.

Testing Cement

43. Cement is tested and approved by representatives of the Laboratory who are stationed at the cement mill. The cement is taken from approved bins and loaded into cars or truck tankers for shipment under their supervision. The Inspector at the cement mill places an Acceptance Card, Form 4111, on the car or truck and secures the doors with Department seals. Cement received at the Contractor's plant identified in this manner may be unloaded, stored, and used without any further testing. The Plant Inspector, however, should remove the Acceptance Card and seals, record in proper place in plant book, and should retain all of them in his office until the completion of the project or until they are required to be sent to the District Office.

If a shipment of cement comes to the plant without Form 4111, the District Materials Engineer should immediately be given the name and number of the shipment and the date on which it arrived at the plant. With this information, he can check with the Laboratory and find out whether or not the cement has been approved at the plant. Form 4111 may have been attached at the plant and become lost in transit. The cement must not be used until permission has been given by the District Materials Engineer. If Form 4111 is attached to the car but the seals have been broken, the District Materials Engineer should be consulted immediately for further instructions.

Handling of Cement

44. Cement must be stored carefully so that it will be kept dry. It should never be placed in contact with the ground. Any cement held in storage over the winter is not to be used until re-tested and approved by the Laboratory. If a shipment of cement without an Acceptance Card must be unloaded before the results of the tests on it are known, the cement should be stored separately, so that it can be readily identified in case an unfavorable test report is received.

When bulk cement is being transported from the proportioning plant to the mixer, approved tight containers must be used. The Inspector on the cement bin is responsible for checking the accurate weighing of the cement in each batch. From time to time the Mixer Inspector should check the contents of a container when the truck arrives at the mixer. It may be desirable to make a mark in each container at the proper level of the cement required for a batch. The weight governs*, but such marks will provide the Mixer Inspector with a reasonably accurate check.

Truck Mixers

45. A truck mixer may be used for the entire mixing of concrete in transit, or the completion of the mixing of partially-mixed concrete. Such a mixer must conform to the requirements of the Specifications. It has to be equipped with a revolution counter which can be reset. The manufacturer must attach to it a metal plate on which is stated its rated capacity, in terms of cubic yards of mixed concrete, for each kind of use. When the manufacturer guarantees that the mixer can mix completely an additional 1/2 cubic yard over its rated capacity the additional capacity may be used. The minimum and maximum numbers of revolutions of the drum in the mixing period under various conditions and the limiting numbers of revolutions per minute are given in the Specifications. The total lapsed time between proportioning of the materials and placing of the concrete, and the method of delivering the concrete, must conform to the requirements of the Specifications.

The measuring device on the water tanks mounted on a truck mixer must be readily adjustable. Also, when the truck is stationary and level, the error in the measurement must not be more than 1 percent of the total water-measuring capacity of the tank. The water tank must be equipped with outside taps or valves to allow its calibration to be checked, unless other means are provided for accurately checking the measuring device. When the water tank is being filled, the truck must be level, so that the gage on the tank will show the actual amount of water in the tank.

Concrete Mixed at Central Plant

46. The requirements given in Section 45 for water tanks on truck mixers also apply to tanks at central plants. Concrete mixed at a central plant must be transported to the site of the project in approved vehicles. A paving mixer may be used as the central plant. All agitator trucks, or all truck mixers used as agitators, for hauling plant-mixed concrete on one project must be of similar design. Each vehicle must be equipped with a revolution counter.

Requirements of Batch Proportioning Scales

47. Batch scales, such as those used for proportioning aggregates for portland cement concrete or bituminous concrete, portland cement, asphalt, and other construction materials, must be checked frequently. A seal on a scale means only that the scale was accurate within certain limits under the conditions existing at the time it was tested and sealed. Dirt on the balance arms, damage to or wear of the knife edges, settlement of the foundation, mechanical work, or unauthorized adjustment can change the accuracy of a scale from one day to the next.

To get the right proportions of aggregates and other materials in a mixture, each material must be weighed accurately. For this reason, it is absolutely necessary that all scales be checked for zero balance and sensitivity several times a day, and tested for accuracy, when fully loaded to the batch weight, at least once a day. If a load of known weight is put on a scale and the reading on the dial or beam is exactly the same as the known weight, the scale is accurate. If the change in the beam or dial reading shows correctly an increase or reduction in the full batch weight equal to that measured by one-half the smallest division on the beam or dial, the scale is sensitive. According to the Specifications, a scale must meet the following requirements when fully loaded with the heaviest batch usually weighed on it: A scale for weighing portland cement and aggregates for concrete must be accurate to 1/2 percent and the scale increments not more than 1/1000 of the scale capacity. A scale used for weighing aggregate for bituminous concrete must be accurate to 1/2 percent and must be sensitive to one-half the smallest division on the beam or dial. This smallest division must not represent more than 10 pounds. A scale used for proportioning bituminous material (asphalt or tar) must be accurate to within 1/2 percent and must be sensitive to a change in weight of 2-1/2 pounds.

The Specifications also require that the Contractor have on hand at a proportioning plant at least ten standard test weights, each weighing between 49.5 and 50.5 pounds. These weights must be kept clean and stored where they will be convenient for calibrating* the scales. The weigh hopper should have an attached shelf around the outside on which the tests weights can be placed.

Daily Test of Scales

48. Each scale must be tested, and the results of the test recorded, every day aggregates are to be weighed. The test should be made early in the day, or at some convenient period during the day, so that proportioning and construction work will not be held up. When the scales are being tested, the bins should be filled, as their weight may bend the steel members to which the scales are attached and affect weighing accuracy. The Inspector should first do the following things:

Check the weigh hopper to make sure it is empty and no material is stuck to it.

See that the scale arms are normally clean and that nothing is resting on or against them.

Make sure no one is touching or leaning against the scale or hopper

See if the beam of the scale balances when the indicator is set at zero, or if the hand on the dial reads zero. If this is not the case, the scale must be adjusted for balance.

If the scale is used for weighing small batches, as for asphalt, the test is made as follows: Test weights are placed on the shelf in 50-pound increments until the total weight is slightly above the usual batch weight. The actual weight and the weight shown by the scale are recorded.

If the scale has a higher capacity, the ten test weights totaling 500 pounds are placed on the shelf, and the scale reading is recorded. Then the test weights are removed and material is drawn into the hopper until the scale reading is exactly the same as that found by using the ten test weights. All the test weights are again added, and the new scale reading is recorded. The test weights are again removed, and more material is drawn into the hopper until the second scale reading is obtained. This procedure is continued until the scale reading is more than the total weight of the heaviest batch to be proportioned on the scale. At this point, the sensitivity of the scale should be measured by adding 2-1/2 or 5 pounds to the test weight. If a small weight is not at hand for this purpose, one can be made by weighing the right amount of sand or coarse aggregate in a can or other container on a small scale or balance.

A dial scale must be checked for the weight of each material in a batch. If sand is to be weighed first, the scale is checked for the weight of sand in the batch and also for the total weight of the sand and coarse aggregate. The exact weights cannot be checked with the 50-pound test weights alone, but it is accurate enough to check weights near the batch weights. For example, if the sand in a batch is to weigh 1236 pounds the scale can be checked at 1250 pounds; and if the combined weight of sand and coarse aggregate is to be 3396 pounds, the check can be made at 3400.

The method of recording on Form 4221 the results of a test on a scale is shown by the following example:

Date - 1959	9/28
Checked by	Mike
Beam Reading - 500	499
Tolerance Determined (2.5 lb)	-1
Beam Reading - 1000	1000
Tolerance Determined (5 lb)	--
Beam Reading - 1500	1500
Tolerance Determined (7.5 lb)	--
Beam Reading - 2000	2002
Tolerance Determined (10 lb)	+2
Beam Reading - 2500	2503
Tolerance Determined (12.5 lb)	+3
Beam Reading - 3000	3003
Tolerance Determined (15 lb)	+3
Beam Reading - 3500	3504
Tolerance Determined (17.5 lb)	+4
Beam Reading - 4000	4004
Tolerance Determined (20 lb)	+4
Beam Reading - 4500	
Tolerance Determined (22.5 lb)	
Beam Reading - 5000	
Tolerance Determined (25 lb)	

Checking Scale for Balance and Sensitivity

49. To check a beam-type scale for balance, the Inspector should slide all weights to zero position. If the beam does not balance, either something is stuck in the weigh hopper or the scale is out of order. The trouble should be corrected before any more batches are weighed.

When the scale is of the dial type, the hand should return to zero on the dial after the weigh hopper is emptied. In case it does not, something is probably stuck in the hopper. If the reason for the improper reading is found the necessary adjustment should be made before any more batches are weighed.

The most common trouble with a scale is lack of sensitivity when the weigh hopper contains a full batch. To check the sensitivity of a scale, a full batch should be placed in the hopper, and the exact weight read on the beam or dial. Then a 50-pound test weight should be added on the weigh hopper. The increase in weight should be in proportion to the weight of the full batch, within the allowed tolerances. The knife edges which support the scale arms may be worn or dirty, some object may be touching these arms, or something may be preventing the free movement of the weigh hopper.

Checking Total Weight of a Batch

50. The total weight of materials for a batch of portland cement concrete in either a truck or a truck mixer, or the weights of a batch of bituminous concrete, can be checked approximately by the use of a truck scale. The empty truck prepared for loading is driven onto a platform scale, and its weight is recorded. It is then loaded with one or more batches, and returned to the scale, and the total weight is found. If the distance from the scale to the proportioning plant is 1 mile or more, a correction must be made for the gasoline used between the first and second weighings. This correction can be estimated at about 1 pound per mile, but it is best to have the fuel tank filled completely each time the truck is weighed.

Example: The weight of an unloaded truck is found to be 14,490 pounds. The truck is then driven 3 miles to a bituminous concrete plant where it is loaded with three 2-ton batches of asphaltic concrete. It is returned to the scales, and the load weight is found to be 26,440 pounds. The work for the weight check is recorded as follows:

Weight of truck and load	26,440 pounds
Weight of unloaded truck	14,490
Difference	11,950
Correction for gasoline	+ 10
Computed weight of 3 batches	11,960
Correct weight of 3 batches	12,000
Error	40

Percent error = (40/12,000) x 100 = 0.33 percent

Since the scale weights are accurate only to the nearest 10 pounds, the correction for the loss of gasoline is rounded off.

Requirements of Meter for Proportioning Bituminous Material

51. Meters and metering pumps used to proportion asphalt or tar for a bituminous mixture should be checked frequently. If the results of several carefully run extraction tests show that there is a difference of more than 0.3 percent between the weight of bituminous material actually used and the weight required by the job mix formula, the meter or pump should be inspected immediately. The accuracy of a meter or pump in good condition may be affected by changes in the pressure of the liquid at the point at which it goes into the meter or pump, by changes in the temperature and penetration of the bituminous material, or by changes in the back pressure caused by partial clogging of the spray nozzles or openings in the spray bars.

Since the required percentage of bituminous material in the mixture is specified on a weight basis, the accuracy of a meter should be checked by weighing a measured quantity of the bituminous material at least equal to that used in a batch or in about 2 tons of mixture in the case of a continuous plant. The check should be made with a sample of the material used in the mixture. The temperature of the measured material should be the same as that under usual operating conditions. When the temperature of the bituminous material changes more than about 15 degrees F under different operating conditions, measurements should be made at both the highest and lowest temperatures to find how much effect a certain change in temperature has on the quantity of asphalt delivered.

The system for delivering bituminous material must include a bypass to permit discharge of the material into a weigh drum instead of into the mixer. This bypass must have a throttle valve to regulate the rate of flow through the meter or pump, so that the back pressure will be the same as that under operating conditions.

Test of Meter

52. To test a meter for proportioning asphalt or tar, it is necessary to have the following equipment:

1. Platform scales with a 200-pound capacity sensitive to 0.5 pound.
2. A metal drum, or other tight container, with a 50-gallon capacity. After the test it is usually thrown away without being cleaned, but most of the bituminous material may be dumped out and the rest burned out.

Before the test is made, the meter or pump must be set for the quantity of bituminous material usually used in the mixture, at the proper temperature. Also the rate of discharge of asphalt into the mixer under operating conditions must be checked, and the discharge of the meter or pump must be changed from the mixer to the bypass in the delivery system. The bituminous material should be discharged into a waste container until the piping is heated. At the same time the rate of discharge must be adjusted by means of the throttle valve to agree with the normal rate during mixer operation.

The test procedure is as follows: The 50-gallon drum (or other container) is weighed accurately, and the weight is recorded. Also, the reading of a continuous meter or the revolution counter in a continuous plant is recorded. The meter or pump is then operated while 30 or more gallons of bituminous material is discharged into the weighed drum. The temperature of the asphalt in the drum and the final reading on the continuous meter or revolution counter are recorded. The drum and its contents are weighed, and the weight of the empty drum is subtracted to get the weight of bituminous material used. The difference between this weight and the weight which should have been placed in the drum according to the meter or pump readings is the error of the meter or pump. To express this error as a percent, the error is divided by the weight which should have been placed in the drum, and the result is multiplied by 100.

The error of a meter or pump should not be more than 0.1 percent. If it is over 0.5 percent, the test should be repeated. If the error is still 0.5 percent or more, the meter or pump should be adjusted or repaired by the Contractor before more of the mixture is produced. After being adjusted or repaired, the meter or pump must be retested.

When test data are being recorded, the amount of bituminous material in the supply tank should be noted. The results of tests made with a nearly full tank may differ from those obtained when the tank is nearly empty.

Importance of Moisture in Aggregates

53. Moisture in aggregate is of two kinds: moisture absorbed by the aggregate, and free moisture on the surfaces of the aggregate particles. The free moisture content of a sample of aggregate, in percent, should be found by dividing the weight of the moisture by the weight of the aggregate in a saturated surface-dry condition, and then multiplying the result by 100. Aggregate is in a saturated surface-dry condition when it has absorbed as much moisture as possible but there is no free moisture on the surfaces of the particles. It is not practical to get aggregate exactly in this ideal condition. However, the weight of saturated surface-dry material can be found from the weight of damp or wet aggregate by simple arithmetic. If the total weight of moisture and the weight of absorbed moisture in the aggregate are known, the weight of free moisture is equal to their difference. Then, to get the weight of the saturated surface-dry aggregate, it is simply necessary to subtract the weight of the free moisture from the weight of the damp or wet aggregate.

When saving time is more important than getting extreme accuracy, as when the percentage of free moisture in aggregate is to be found by making a test in the field, it may be assumed that the moisture content, in percent, is based on the weight of perfectly dry aggregate.

For practical purposes, it may be assumed that the absorptive capacity of a particular aggregate does not change. The absorptive capacities of all kinds of aggregates are given in Department Bulletins 13 and 14. An ordinary aggregate does not usually absorb more than 1 percent of its weight, but blast-furnace slag may absorb as much as 5 percent. The total moisture content of an aggregate depends on the weather conditions and other factors. It must be determined by a test.

The moisture contents and the absorptive capacities of aggregates to be used for cement concrete are important in proportioning the materials in the following two ways:

1. The weight of water added to the aggregates and cement in the mixer must equal to the difference between the total weight of mixing water required in the batch and the weight of free moisture already in the aggregates. If the moisture content of an aggregate changes by 1 percent and the amount of water added at the mixer is not adjusted to allow for this change, the slump of the concrete may be changed by as much as 1-1/2 inches.

2. The weights of damp or wet aggregates used in the various batches of concrete must be adjusted so that all batches of concrete will contain the same weight of saturated surface-dry aggregates.

According to the Specifications, all aggregate for cement concrete must be stored at least 18 hours before it is used, and its total moisture content must be kept uniform and greater than its absorptive capacity. For this reason, every proportioning plant must be equipped with a suitable system of water sprays to keep the coarse aggregate damp enough. A spray system is not needed for wetting stockpiles of fine aggregate, but means should be provided for adding moisture to the outside layers of such stockpiles in case of necessity. A spray system should be so operated that the moisture content of the aggregate remains uniform. It may not be necessary or desirable to apply water at all times. If the total moisture content of the aggregate in a stockpile is never allowed to drop below its absorptive capacity, the aggregate will not absorb any of the water added at the mixer.

<u>Determining Moisture Content of Aggregate</u>

54. A laboratory test for the moisture content of an aggregate should be made with such precision* that the results will be accurate* to the nearest 0.1 percent. When a field test must be made to determine the moisture content of sand, speed in performing the test is very important. Unless information on a change in moisture content is available in time to make the proper adjustment in the batch weight, the test serves little purpose.

The weight of free moisture in a sample of either fine or coarse aggregate may be determined as follows: The sample is weighed while damp, is thoroughly dried by means of heat, is then weighed again. The loss in weight represents the total moisture. The weight of free moisture is found by subtracting the absorptive capacity of the aggregate from the total moisture.

The frequency with which tests for moisture content should be made depends on the rapidity of changes in the stockpiles. Ordinarily each material is tested twice a day. Additional tests are made whenever conditions change noticeably. Owing to the inaccuracies which occur in sampling and weighing, the sample for a moisture test should be as large as can be handled conveniently in the time available.

From experience with the aggregates being used and the results of regular moisture tests, the Inspector should soon be able to judge with reasonable accuracy when any large changes occur, and he should make additional tests whenever they are required.

<u>Details of Field Tests for Moisture Content</u>

55. Unless otherwise directed, a field test for the percentage of free moisture in a fine aggregate is made as follows:

<u>Step 1.</u> A small dry metal pan or dish is weighed, and its weight is recorded. Assume, for example, that it weighs 56 grams (a gram is the unit generally used for small quantities).

<u>Step 2.</u> A sample weighing at least 500 grams is collected from different parts of a batch or stockpile of sand; this sample is placed in the pan; and the total weight of the pan and sand is found and recorded. Assume that this total weight is 589 grams.

<u>Step 3.</u> The pan with its contents is placed in an oven or over a source of heat until it is perfectly dry. If an oven is not used, the sand should be carefully stirred with a trowel, spoon, or other tool in such a way that no particles of sand are lost, but so that any moisture can escape. As soon as the sand is dry, the pan is removed from the heat and the sand is allowed to cool to the air temperature. A sample is dry when its weight becomes constant.

An initial check on thoroughness of drying may be made by slowly passing a cool piece of glass or mirror just above the surface of the sample. Fogging of the glass shows that moisture vapor is still coming off.

<u>Step 4.</u> When the sand has cooled, the pan and its contents are weighed again (a hot pan should never be put on a scale or balance), and this weight is recorded. Assume that it is 565 grams.

<u>Step 5.</u> The percentage of free moisture is computed. If the weights assumed in Steps 1, 2, and 4 are used, here is the work.

Weight of damp sand = 589 - 56 = 533 grams

Weight of dry sand = 565 - 56 = 509 grams

Total weight of moisture in sand = 533 - 509 = 24 grams

Percent total moisture in sand = (24/509) x 100 = 4.7 percent

You should note that the percent moisture is based on the weight of perfectly dry sand.

If the absorptive capacity of the aggregate is given in Bulletin 14 as 1.2 percent, percent free moisture = 4.7 - 1.2 = 3.5 percent

The moisture content of a coarse aggregate may be found in a similar way, but the test sample should weigh at least 1500 grams. A separate test for moisture content should be made on each size of aggregate used.

Another way of determining the percentage of free moisture in a coarse aggregate is as follows: A dry container and the container with the damp sample in it are weighed, and the weight of the damp sample is found by subtracting one weight from the other. The free moisture is then removed from each particle by wiping it with an absorbent cloth until its color begins to change from dark to light. The aggregate will now be approximately in the saturated surface-dry condition, and its weight in this condition should be found by subtracting the weight of the empty container from the weight of the container with the surface-dry aggregate in it. The sample must now be dried completely and the dry weight found. The percent free moisture is computed by subtracting the weight of the surface-dry sample for the weight of the damp sample, dividing the difference by the weight of the dry sample, and multiplying the result by 100.

Sieves for Determining Gradation of Aggregates

56. Just by looking at a small quantity of sand for concrete or of a mixture of sand and gravel taken from a pit, it is easy to see that all the particles do not have the same size. To learn how such a material will act and if it is suitable for use in a certain type of construction, the gradation of the material, or the proportions of the various sizes of particles in the material, must be determined. For this purpose the particles in a sample are separated into different size ranges by the use of standard laboratory sieves. A sieve is made of woven wire, with square openings between the wires. Usually the wire fabric is fixed in a round frame, and the frames are so made that one may be fitted to another.

There are about fifty standard sieves which differ from one another in the sizes of the openings. However, those in general use for determining the gradation of aggregate are listed in Table IV. As shown in this table, sieves with openings larger than 1/4 inch square are named by the length of one side of an opening in inches; while sieves with smaller openings are given numbers which show how many openings there are in each inch of the sieve. You should note that the size of opening for any sieve in the series in Table IV is almost exactly twice that for the next smaller sieve. This relationship has many advantages. If the Specifications require the use of other sieves, the method of determining the gradation of the material is the same.

TABLE IV - Sizes of Sieve Openings

Sieve Size, in Inches, or Sieve Number	Size of One Side of Sieve Opening, in Inches
3 in.	3.0
1-1/2 in.	1.5
3/4 in.	0.75
3/8 in.	0.375
No. 4	0.187
No. 8	0.0937
No. 16	0.0469
No. 30	0.0232
No. 50	0.0117
No. 100	0.0059
No. 200	0.0029

The frame of a standard sieve will have on it a metal plate on which is shown "U.S. Standard Sieve No._____." Each sieve used in a test for determining the gradation of aggregate must be in good condition. It must not have any openings that are "blinded", or stopped up; and there must be no breaks in the wire fabric or places where the fabric has become detached from the frame. Also, the sieves of a set must fit together easily. When a set of sieves is used in a test, the bottom sieve must fit into a pan, and the top sieve must have a tight-fitting cover.

Sieves are expensive, and they should be protected when not in use by keeping those of a set (including the pan and cover) fitted together in proper order in a stack. A sieve should never be used as a container for storing food or an aggregate sample or for weighing aggregate. The wire fabric in some sieves is held in place in the frame by solder. If a sieve is heated in an oven, the solder may melt and the sieve may be ruined. If the sieves of a set must be pried apart, they do not fit properly. Handling them roughly to separate them may damage them further, or may cause a part of the sample to be lost. A plant operator's mechanic should be able to restore a battered sieve to good condition by straightening and filing the skirt.

Equipment for Gradation Test

57. The equipment needed in a test for determining the gradation of aggregate includes a scale or balance for weighing the material, a set of sieves, brushes for cleaning sieves, and weighing pans.

When a gradation test is made on a small sample, the scale or balance should be sensitive enough to keep the error in any weight less than 0.1 percent of the total weight of the test sample. For instance, if the weight of a sample of fine aggregate is to be 500 grams, the balance must be accurate to the nearest 0.5 gram. If a sample of coarse aggregate will weigh about 15 pounds, the scale need be accurate to about the nearest ounce; but greater accuracy would be required for a smaller sample.

Tests are meaningless when made with sieves that have splits in the wire fabric or are blinded. If the wire fabric has been pulled out of the frame, repairs may be made with Duco cement. Sieves with very small openings become blinded easily.

Blinding of a sieve is caused by not cleaning it after each use, making a test with too much material in the sieve, or leaving the sieve for too long a time in a mechanical shaker. If properly used, a sieve should last for many years without becoming stopped up.

If a blinded sieve is held up to the light, it will be seen that many of the openings are stopped up by wedged pieces of aggregate. A blinded sieve can usually be cleaned by holding it upside down and using a suitable brush. For sieves smaller than No. 30, a 3-inch paint brush with the bristles trimmed to a length of about 1 inch is best. For larger sieves, a suede brush with brass bristles may be used. Tapping the wire fabric lightly with the bristles, with a motion like that for using a stencil brush, should push out the wedged particles.

The aggregate retained on each sieve of a set must be weighed. Light metal pans about 12 inches in diameter, such as pie tins, are commonly used to hold aggregate during the weighing operation.

Dry Sieve Test of Fine Aggregate

58. For aggregates passing a 3/8 inch sieve, the sample used in the gradation test should not weigh more than can be handled in a 6" sieve. It should be obtained by quartering or splitting a representative sample that weighed about 10 pounds. The weight should not be adjusted to get a convenient number of grams, such as 500. The sample must be dried, in an oven if possible. If it is heated in a pan, the sample should be stirred constantly, and care must be taken not to heat it above 240 degrees F. Some aggregates "pop", or split down, when heated to a high temperature, with the result that the test shows a finer gradation than the aggregate actually has. The heated sample should be allowed to cool in the air until it is not uncomfortably warm to the hand. Dumping hot aggregate into a sieve will ruin the sieve.

To make the test, the sizes of sieves required by the Specifications are fitted together on the bottom pan. The sieves should be arranged so that the name plates are above one another and the sieve numbers should be checked to make sure that each sieve has larger openings than the one below it. The entire test sample is placed in the top sieve, and the cover is put in place. The sieves must be shaken until aggregate particles no longer pass through any sieve. If a large amount of the sample is made up of particles of one size, it is best to use extra "dummy" sieves between the required sieves. Extra sieves prevent too much material from piling up on one sieve. After the sieves have been shaken, the layer of material on any one sieve should not be more than two particles deep.

It is often quicker and more convenient to shake the sieves by hand instead of using a mechanical shaker. If the sieves are shaken by hand, a stack at least six sieves high should be used. If necessary, "dummy" sieves should be placed between the required sieves. With the stack set on a hard level surface, such as a bench top or on a wood floor, the heel of the hand should be placed on the center of the cover so that the first joint of each finger is crooked over its edge. The arm should be held straight, and the hand swung in an arc so that the sieve stack rocks from one side of the pan to the other side. If the right hand is being used, the tips of the fingers should touch the side of the top sieve when the stack is rocked to the left. This action will rotate the stack slightly. The purpose of turning the stack is to have the aggregate particles slide across the sieves in a different path each time, while the rocking action jars the sieves so as to remove stuck particles from the sieve openings. When the sieves are shaken in this way, a sieve test may be completed in as little as 5 minutes.

After the sieves have been shaken, either by machine or by hand, a check should be made for the completeness of the sieving. For this purpose, a piece of paper, such as a newspaper, which is large enough to prevent loss of aggregate, is spread on the bench top (white paper is best). Then the cover is taken off the stack of sieves, and the top sieve is removed and held in the hand over and close to the paper. This sieve is swung about 6 inches and tapped against the heel of the other hand again. If any aggregate particles fall on the paper, it should be picked up carefully, and these particles placed in the next smaller sieve, which is now on the top of the stack. Shaking and tapping of the top sieve is continued until no more particles fall on the paper. This sieve with the aggregate remaining in it is put aside, and all particles on the paper are poured into the next smaller sieve. This second sieve is then removed, shaken, and tapped in the manner just described for the top sieve, and the operations are repeated for each other sieve in the stack. If many particles pass through any sieve during this extra shaking, the stack of sieves was not shaken long enough or in the right manner, or the shaking was defective in both respects.

Usually the gradation is indicated by the percentage of the sample passing each of the sieves. It is then easier to make the calculations when the aggregate is weighed in the following manner: A small flat pan, such as a pie tin, is put on the balance. If possible, this pan is tared to bring the reading of the balance to zero. If the pan cannot be tared, its weight is recorded.

The bottom pan is removed from the stack of sieves, and its contents are dumped into the tared pan on the balance. The material in the tared pan is weighed, and this weight is recorded on Form 427 as the amount passing the bottom sieve. All material is left in the tared pan as it accumulates.

The bottom sieve is removed from the stack, its contents are dumped into the tared pan, and it is then turned upside down in the pan while the wire fabric is brushed lightly. The sieve should then be held up to the light to see if any particles are wedged in the openings. Particles that remained in the sieve can be removed by first holding the sieve upside down over a large piece

of paper spread on the bench top and tapping its upper edges, and then laying the sieve upside down on the paper and brushing its bottom. Tapping and brushing should be continued until the sieve is clean. The paper is picked up, and all the aggregate on it is poured into the tared pan. All the material in the tared pan at this time is weighed, and the weight is recorded on Form 427 as the accumulated amount passing the second sieve from the bottom.

Next, all the material remaining on the second sieve is dumped into the tared pan, care being taken to get out all particles that may have become wedged in the openings. The weight of all the material now in the tared pan is recorded on Form 427 as the accumulated amount passing the third sieve. These operations are repeated until the top sieve has been emptied and the entire sample is in the tared pan. In Table V is shown a typical record on Form 427.

The accumulated weight passing a sieve is the total weight of all material in the tared pan after all sieves smaller than the one in question have been emptied into the pan. Thus, the accumulated weight opposite the No. 30 sieve, or 243 grams, includes all the material taken from the bottom pan, the No. 100 sieve, and the No. 50 sieve.

Each percent in Column C in Table V is computed by dividing the weight recorded in Column B opposite the sieve size by the total weight at the foot of Column B, and then multiplying the result by 100. For example, the percent passing the No. 30 sieve is (243/517) x 100 = 47.0.

TABLE V - Results of Gradation Test

(A) Sieve Size	(B) Accumulated Weight Passing	(C) Percent Passing
Pan		
No. 100	26	5.0
No. 50	109	21.1
No. 30	243	47.0
No. 16	336	65.0
No. 8	419	81.0
No. 4	476	92.1
3/8"	517	100.0

If the pan on the balance is not tared, the weight of the pan must be subtracted from each weight read on the balance.

Gradation of Fine Aggregate by Volume

59. Gradation of fine aggregate by volume is to be used only with the permission of the Materials Engineer. The procedure for passing the sample through the sieves is exactly the same as that described in Section 58 for gradation by weight. Thus, the material is screened through the 3/8-inch sieve first, then through successive sizes, and finally through the bottom sieve. Each sieve must be carefully shaken until no more material passes through it.

To measure the volume passing the bottom sieve, all the material in the bottom pan is poured into a 200 cc (cubic centimeter) graduate, which is a narrow glass container with a graduated scale on it. The graduate is tapped lightly to compact the material, the surface is leveled off, and the volume is read and recorded on Form 427. The material from the bottom sieve is now put into the graduate, and the total volume is recorded as the amount passing the second sieve from the bottom of the stack. The process is repeated until the volume of the entire test sample is determined. Each percent on Form 427 is computed in the manner explained for gradation by weight.

<u>Interpretation of Results of Gradation Test</u>

60. If the results of the gradation test fall within the limits in the Specifications for the particular fine aggregate under test, the aggregate is acceptable for use insofar as gradation is concerned. However, the limits in the Specifications are recognized as tolerances on a mean gradation. Any marked variation from the normal gradation should be called to the attention of the District Materials Engineer; if the gradation has to be corrected, the Contractor must be notified at once, since the change may affect the workability and production of the mixture in which it is used.

<u>Test of Fine Aggregate by Washing</u>

61. In addition to meeting other gradation requirements for dry sieving, fine aggregates for use in other than bituminous mixtures must pass the silt test. The term silt here means all material that will pass the No. 200 sieve. The percentage of silt in a fine aggregate may be determined either by volume or by weight. The two methods give different results. The percent by volume is roughly twice that by weight. However, the actual correlation* for a particular material should be confirmed at the beginning of the work from a sample submitted to the Laboratory. The requirements of the Specifications are based on the percent by weight. The procedure for determining the percent by weight by the washing method is as follows:

The weight of a test sample should be at least 500 grams. The sample is dried to constant weight on a hot plate, constant stirring being necessary to prevent overheating of the material. In this test, overheating the aggregate not only may change the gradation, but will bake the fine material onto the surfaces of the aggregate particles so that washing will not remove it easily. After being dried, the sample must be weighed accurately.

The sample is now put in a large pan, such as a small dishpan, and covered with water. The aggregate should be stirred rapidly in the water so that all the fine material will be washed from the surfaces of the aggregate particles. When the water has become muddy, it should be allowed to stand for 10 to 15 seconds, in order that the fine sand will settle out. The next step is to wet a No. 200 sieve and to pour the muddy water from the pan through the sieve carefully. No aggregate should get on the sieve, which is used to prevent <u>accidental</u> loss of aggregate.

More water should be added to the aggregate in the pan, the aggregate stirred, and the muddy water poured through the sieve. These operations must be repeated until the water remains clear. The washed aggregate is then put into

a tared* drying pan, the washing pan being rinsed out if necessary to remove all aggregate particles. As much water as possible should be drained from the drying pan, but care must be taken not to lose any aggregate. The washed aggregate is dried to constant weight, and this weight is recorded.

The difference between the weights of the dry unwashed material and the dry washed material is the loss in weight from washing. An example follows:

Unwashed	(dry)	=	517 grams
Washed	(dry)	=	502 grams

Loss from washing = 15 grams

$$\text{Percent loss} = \frac{15}{517} \times 100 = 2.9 \text{ percent}$$

Gradation Test of Subbase Material in the Field

62. The equipment required for a gradation test to be made on subbase material in the field must include the following: a scale having a 200-pound capacity and accurate to the nearest ounce; a 500-gram balance accurate to 0.1 gram; a hot plate or other source of heat; the standard sieves specified for the test; an extra No. 200 sieve for washing the fine part of the sample; pans for drying the sample; a beaker or glass; and a dishpan or wash basin.

After the sample has been lifted from its position in the road, it is quartered to a convenient size, which is usually between 2 and 6 pounds; the weight to be tested depends on the amount of coarse material. The test sample is dried to constant weight on the hot plate. This drying is the major time-consuming part of the work, but frequent stirring of the material will reduce the time a great deal. The sample should not be overheated. After the dried sample has been allowed to cool, it is weighed, and this weight is recorded as the weight of the entire test sample.

The entire test sample is put on a No. 10 sieve and inspected. If lumps are present, they are broken until the plus No. 10 material, which is the material retained on the sieve, appears to be clean and free from all lumps and dirt cover. A gradation test is then made on the plus No. 10 material in the manner described in Section 58. The results for a typical material are shown in the upper part of Table VI.

That portion of the sample passing the No. 10 sieve is thoroughly blended, and a representative sample weighing about 50 grams is taken out for determining its gradation. The 50 gram sample is placed in a beaker or glass, covered with water and stirred. It is then put on a No. 200 sieve, on which it is washed. In this process, the No. 200 sieve is lifted up and down in water in a basin or dishpan so that the very fine material is washed through the sieve. Great care must be taken not to allow any material to be pushed over the top of the sieve and thus be lost. If necessary, any lumps can be broken up by light rubbing or agitation with the fingers. The washing is continued until the water coming off the sample is clear. The sample is then washed onto a pan and dried on the hot plate until its weight becomes constant. After

*Tared - Balanced by an equal weight or weighed so that the weight can be subtracted.

sample has dried, it is graded by using a No. 40 and No. 200 sieve, and determining the weight passing each of these sieves. Typical results for the fine material are shown in the lower part of Table VI.

TABLE VI - Specimen Subbase Gradation

Weight of dry test sample 4.08 pounds

A	B	C
Sieve Size	Accumulated Weight Passing (Pounds)	Percent Passing
No. 10	0.94	23.0
No. 4	1.43	35.0
3/4 in.	2.88	70.6
1-1/2 in.	3.74	91.6
2-1/2 in.	4.08	100.0
3 in.	4.08	100.0

A	B	C	D
Sieve Size	Accumulated Weight Passing (Grams)	Percent of - 10 Fraction Passing	Percent of Entire Sample Passing
No. 200	4.3	8.6	2.0
No. 40	11.9	23.8	5.5
No. 10	50.0	100.0	23.0

For the plus No. 10 material, each percent in Column C is computed by dividing by the accumulated weight of the entire sample, and multiplying the result by 100. In Table VI, the weight passing the No. 10 sieve is 0.94 pound, and (0.94/4.08) x 100 = 23.0; and the weight passing the 1-1/2-inch sieve is 3.74 pounds, and (3.74/4.08 x 100 = 91.6)

For the minus No. 10 material, each percent in Column C is based on the weight of material that passes the No. 10 sieve. In Table VI, this weight was exactly 50.0 grams. Thus, for the No. 40 sieve, (11.9/50) x 100 = 23.8 percent. It is necessary now to determine the percents in Column D, which are based on the weight of the entire sample. For this purpose, each percent in Column C must be multiplied by 0.230, because 23.0 percent of the material passed the No. 10 sieve. For the No. 200 sieve, 0.230 x 8.6 = 2.0 percent.

Field Test for Silt

63. To determine the percentage of silt in fine aggregate in the field, the first step is to place 100 cc* of the aggregate in a 200 cc glass graduate. Then the graduate is nearly filled with water and is shaken thoroughly. The bottom of the graduate is held in the left hand and the top is closed firmly

with the right hand. The graduate is turned upside down and then held horizontally while being shaken from side to side. The graduate is turned right side up and shaken gently to get rid of any sand particles that stick to the hand over the top.

Next, the graduate is allowed to stand undisturbed for 1 minute (to permit small sand grains to settle out of the silt particles), and a reading is taken at the top of the aggregate. Assume, for example, that it is 98 cc. Finally, the graduate with its contents is allowed to stand overnight (to permit the silt particles to settle from suspension in the water), and another reading is taken at the top of the silt. Assume that it is 104 cc.

The second reading represents the volume of the entire test sample, and the difference between the two readings represents the volume of silt. For the assumed readings, the total volume is 104 cc and the volume of silt is 104 - 98 = 6 cc. The percent silt, by volume, is found by dividing the volume of silt by the total volume, and multiplying the result by 100. The result should be taken to the nearest 0.1. Thus, (6/104 x 100 = 5.8 percent, by volume.

If the percentage of silt, by volume, in fine aggregate is less than 7, the aggregate may usually be considered satisfactory, as far as silt is concerned. At the beginning of the work, the relationship between the percentage of silt by weight and the percentage by volume should be determined by using the result of a test by washing made in the Laboratory of a sample of the aggregate.

<u>Field Test for Organic Impurities</u>

64. If a fine aggregate is listed in Bulletin 14, it usually need not be tested for organic impurities (vegetable matter or acid). When an aggregate must be tested, specific instructions are given by the Materials Engineer. A colorimetric test is then made.

The equipment needed for the colorimetric test consists of a 12-ounce graduated bottle, vials containing 5 grams of caustic soda (sodium hydroxide), and a metal** or glass beaker. Before the test is started, a solution of caustic soda is prepared in this way: water is put into the bottle up to the 5-ounce graduation; this water is poured into the beaker; a stick of caustic soda from one of the vials is added; and the contents of the beaker are stirred until the caustic soda is dissolved.

To make the test, the bottle is filled to the 4-1/2-ounce mark with the fine aggregate, which should be slightly damp. While too much water in the aggregate weakens the testing solution, if the aggregate is first dried, some of the organic matter may be lost in handling or may be burned off. The solution of caustic soda is added to the aggregate until the total volume of the aggregate and the solution, after the bottle has been shaken a little, is 7 ounces. The bottle is then shaken so that the contents are mixed thoroughly, and is allowed to stand overnight. The next day, the color of the liquid above the aggregate is observed.

If the liquid is colorless, or has a slight yellow color, the fine aggregate may be considered satisfactory as far as organic impurities are concerned. If the color of the liquid ranges from dark red to black, however, the

**an aluminum container must not be used.

aggregate is of doubtful quality. Such aggregate should not be used until a sample has been tested for strength** in the Department Laboratory.

Required Samples of Fine Aggregate

65. A great deal of care must be taken in collecting and identifying each sample of fine aggregate. The sample should be truly representative of all the material which will be approved or rejected on the basis of inspection and tests of the sample. To avoid segregation in the lot of aggregate to be sampled, the sample should be taken when the aggregate is in a moist condition. In the process of taking the sample, all material belonging in it should be included. No very fine material should be left behind or lost.

To make sure that a sample is adequately identified, a fully completed copy of Form 447 must accompany each sample. It is better to over-identify a sample than to leave off the Form any detail that may be helpful to the Laboratory technicians. The identification Form should be enclosed in a sample identification envelope, Form 7118, which should be placed inside the sample bag.

Each shipment of fine aggregate should be sampled as soon as possible after it arrives on the project, so that the Contractor can use approved material without delay. The procedure in submitting samples of fine aggregate to the Laboratory is as follows:

a) A sample representing the first 100 tons of fine aggregate delivered on the project should be taken as soon as the aggregate is received, and a portion of the sample sent to the Laboratory immediately. No fine aggregate is to be used until this initial sample has been approved by the Laboratory.

b) A sample of each lot of fine aggregate considered unfit for use or of doubtful quality should be sent to the Laboratory promptly for final decision.

c) When the source of supply of fine aggregate for a project is changed, it again becomes necessary to send to the Laboratory an initial sample representing the first shipment of 100 tons arriving on the work.

d) After the initial sample has been taken, a composite sample representing each 1,000 tons of each grade of fine aggregate received on the project, regardless of the method of delivery, has to be sent to the Laboratory for check testing. The composite sample should be made up of approximately equal individual portions taken from different parts of the lot being sampled. The weight of each individual portion should be between 7 and 10 pounds or approximately the same as the weight of aggregate to be used for field testing or for submission to the Laboratory.

**The strength of a mortar made with the sand is compared with one made with standard sand.

Sand for a sand-cement bed or cushion, filler, or similar use should be sampled, and the samples sent to the Laboratory. A sample should be taken from the first shipment of the material received on the project, from each distinctly different grade in any later shipment, and from any lot of doubtful quality.

Collection of Samples of Fine Aggregate

66. A sample of fine aggregate arriving on the project may be taken from a railroad car, a barge, or a truck. When the aggregate is received in cars, a composite sample for field testing is required for each lot of 250 to 300 tons of material. The composite sample should be made up of individual portions taken from the cars selected for sampling in the following way:

Three pits, which are as deep as possible, should be dug in each car. One should be in the center of the car and one near each end. A sample portion from a pit should be taken by passing a scoop up the entire side of the pit, at several vertical sections which are fairly representative of the material in the car. From each pit sample, an individual portion weighing from 7 to 10 pounds is removed, and these portions are mixed thoroughly on a smooth, clean surface to get a composite sample. Before the portions are mixed, the material in each should contain enough moisture to prevent segregation during mixing. If the material is too dry, water should be added before mixing is begun. Instead of digging test pits, a composite sample may be made up by mixing individual samples taken with a sampling tube.

When fine aggregate is received in barges, a composite sample for field testing is required for each 250 to 300 tons. The test pits should be dug in each section; and the composite sample for the section should be obtained by following the procedure described for car sampling.

When fine aggregate is delivered to a project by truck, each lot of 250 to 300 tons must be kept separated from the general stockpile until it has been field tested and approved. A composite sample for field testing is obtained from each lot by taking individual portions from at least ten pits dug at random, and combining the portions as described for car sampling.

Approval or Rejection of Fine Aggregate

67. The intent of the Specifications is that all fine aggregate delivered to a project should uniformly meet the requirements for a particular item in the Contract. If the fine aggregate in any individual lot appears to be unsatisfactory for any reason, a sample from that lot must be tested separately in the field. Also, a check sample may have to be sent to the Laboratory for confirmation of the results of the field tests. At least once each day a lot of suitable size must be sampled at random, and the sample tested to spot-check the uniformity of deliveries.

A lot of fine aggregate that does not meet all the requirements of the Specifications must be rejected. It may not be used in the work for the intended purpose. The Contractor is responsible for the quality of all materials delivered to the project. Work may have to be stopped until acceptable materials are delivered.

Preparing Composite Sample of Fine Aggregate

68. The first step in preparing a composite sample for testing is to reduce its size to about 5 pounds by quartering or by using a sample spliter.

Approximately 220 grams of the reduced composite sample of moist fine aggregate should be taken for a sieve analysis by "thief" sampling. This material should then be weighed and placed in a pan to be thoroughly dried. Portions of the remainder of the reduced composite sample may be used, if needed, for silt determination, colorimetric test, and determination of fineness modulus and for submission to the Laboratory. A sample forwarded to the Laboratory is to be made up of portions taken from a set of three or four composite samples which have been similarly obtained, and should represent deliveries of approximately 1,000 tons.

Gradation Tests of Coarse Aggregate

69. Coarse aggregate must meet the gradation requirements of the Specifications. The equipment needed for a gradation test includes a platform scale (furnished by the Contractor), canvas bags, buckets, a frame for standard sieves, and a set of the following sieves: No. 8, No. 4, 3/8 inch, 1/2 inch, 3/4 inch, 1 inch, 1-1/2 inches, 2 inches, 2-1/2 inches, 3-1/2 inches, and 4 inches. A test sample of coarse aggregate should have a total weight of from 25 to 200 pounds, the proper amount depending on the size of the largest particles.

The dried test sample is separated into various size ranges by using certain selected sieves which are considered best for the particular sample being tested. The sieve of the selected group with the largest openings is clamped in the upper section of the frame, and the whole test sample is dumped into this sieve. The aggregate retained on this sieve is placed on a clean surface in a pile by itself. The second sieve, with openings of the next smaller size, is clamped in the frame, and all the aggregate which has passed through the first sieve is put into this second sieve. The material retained on this second sieve is set aside in a separate pile. A third sieve with still smaller openings is clamped in the frame, to receive the aggregate which previously passed through the second sieve. The material retained on the third sieve is also kept in a separate pile. The sieving operation is repeated with each other sieve in the group until the last one has been used.

The material passing through the sieve with the smallest openings is weighed, and this weight is recorded. Then the material from each pile is added on the scale, in the order of the sizes of particles from small to large, and the total accumulated weight after each addition is recorded. The percent passing each sieve is computed by using the accumulated weight for that sieve and the weight of the entire sample in the amnner shown for fine aggregate.

Coating on Coarse Aggregate

70. The amount of coating material, such as clay or dust, on particles of coarse aggregate is found by washing the particles thoroughly with water and getting the weight of the material thus removed. A separate washing test should be made on each size of aggregate. This test is not made on all coarse

aggregate received on a project, but is necessary only when a coating is detected by visual inspection. The test sample should represent the entire lot that is considered of doubtful quality. The whole sample should not be taken from a small area in which large amounts of dust and fines tend to collect, such as an area near the peak of a pile formed by discharging aggregate from a bin or an area of segregated fine material in aggregate dumped from a truck. The sample should weigh at least 50 pounds if the aggregate meets the gradation requirements of Pennsylvania No. 1B, No. 2, or No. 2B; and it should weigh between 75 and 100 pounds if the aggregate is No. 3A or No. 4.

The first part of the test procedure is as follows: All free moisture and absorbed moisture in the test sample is driven off by heating the sample until its weight remains constant. This weight is recorded. Care must be taken to avoid the loss of any dust or clay that is loosened in the drying process.

In the next part of the test, the sample is put in a bucket of water and washed until all the particles are free from coating material.

The larger particles are then removed and placed on a clean surface. Also, the water if poured through a No. 100 sieve, extreme care being taken to avoid damage to the sieve. The material retained on the sieve is returned to the bucket or sample container, and clean water is added. The sieving and washing operations are repeated until the wash water is practically clean.

In the last part of the test, the coarse particles of aggregate and all of the material retained on the No. 100 sieve are dried completely by heat. All the dried material is weighed, and this weight is subtracted from the weight of the original dry sample to get the weight of coating. The percentage lost by washing is calculated in the usual manner. As an example, values for a test on Pennsylvania No. 1B stone follow:

Weight of original sample	50.00 pounds
Weight of washed sample	49.75 pounds
Weight lost	.25 pounds

Percent loss = (0.25/50.00)x 100 = 0.50 percent

Other Undesirable Material in Coarse Aggregate

71. Coarse aggregate should not contain excessive amount of shale, clay lumps, and flat and elongated pieces. Shale can usually be recognized by its smooth, soapy feel and its thin layers. Also, it is so soft that it can be easily scratched with a copper panny and can be turned into powder by scraping its surface with the blade of a pocket knife. A piece of stone is considered flat and elongated if it is retained on a 1-inch sieve and its greatest thickness or depth is less than one-fourth its greatest dimension.

In the test for shale, a representative sample of the aggregate weighing not less than 100 pounds is dried, and its weight is recorded. Then all shale is removed by hand, the remaining aggregate is weighed, and the loss of weight is taken as the amount of shale, The percent of shale can be computed in the usual way.

The procedure for determining the percent of clay lumps in coarse aggregate is similar to that for the percent of shale. The only difference is the removal of clay lumps instead of shale.

In the test for flat elongated pieces, an extra step is necessary. The test sample, which should weigh not less than 100 pounds, is weighed and then put on a 1-inch sieve. The material that passes through this sieve is kept and set aside.

Then all pieces which appear to be flat and elongated are removed from the material retained on the sieve. The dimensions of these pieces are measured, and any which are actually unsatisfactory are discarded. The others are put back on the sieve. The material that is left on the sieve and the material which passed through it are combined again, and their total weight is taken as the weight of the sample without flat and elongated pieces. The percent of flat and elongated pieces is computed in the usual way.

Unit Weight of Coarse Aggregate

72. On Form 487, Field Grading Tests of Coarse Aggregate, the unit weight of coarse aggregate, in pounds per cubic foot, is to be recorded under each different grading. One copy of this form is to be sent to the Laboratory with each sample submitted, and another copy is to be sent to the District Office.

The equipment needed for determining the unit weight of coarse aggregate is a standard cylindrical metal measure having a volume of exactly 1 cubic foot, and a scale or balance which has a capacity of 200 pounds and is accurate to the nearest 0.25 pound.

To make the test, the measure is filled with material taken from an air-dried sample of the aggregate. This material is placed in the measure in three approximately equal layers, and each layer is compacted by placing the measure on a firm foundation (such as a cement floor), raising two opposite points on the base of the measure alternately about 2 inches from the foundation, and each time allowing the measure to drop so that it will hit the foundation with a sharp, alapping blow. To get adequate compaction of each layer, the measure must be raised and dropped 50 times, 25 times on each side. After the top layer has been compacted, the surface of the aggregate should be made level with the top of the measure by using the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate balance the larger voids in the surface below the top of the measure.

The net weight of the aggregate in the measure is computed by subtracting the tare weight of the empty measure from the total weight of the measure and the aggregate in it. Since the volume of the measure is exactly 1 cubic foot, the measured net weight is the unit weight of the aggregate.

When slag is used as the coarse aggregate, the average unit weight of three air-dried samples should not be less than Specification requirements, and the unit weight of an individual air-dried sample should not be less than 95 percent of this specified average value. If the average weight of the slag as received exceeds the specified average value by more than 5 percent, the

slag need not be air-dried before the unit weight is determined, but excess free moisture must be drained from the sample before the weight test is made.

Required Samples of Coarse Aggregate

73. Coarse aggregate may consist of broken stone, gravel, or air-cooled slag from a blast furnace. It may be delivered by railroad car, barge, or truck. Each shipment of coarse aggregate should be examined carefully as soon as it is received on the project, to determine if the material meets the general requirements of the Specifications. Stone or gravel must be reasonably uniform in gradation, clean and free from flat and elongated particles. Slag must be reasonably uniform in gradation and density and should not contain excessive amounts of undesirable materials.

Samples of coarse aggregate for field tests should be taken as soon as possible after the material is received, so that the Contractor can use approved material with the least delay. Each day stone or gravel is delivered to the project, four samples for field tests should be taken at random from a car, barge, or truck. For each 400 tons of slag, it is necessary to take three samples for field tests for weight and one sample for a field test for gradation.

The requirements for sending samples of coarse aggregate to the Laboratory are as follows:

Regardless of the method of delivering the material, a sample that represents the first 100 tons of aggregate received on the project, and that is part of a composite sample on which the necessary field tests have been made, must be sent to the Laboratory as soon as possible after the field tests have been completed. Other samples must be sent to the Laboratory when field tests indicate that the material in a lot is unfit for use or of doubtful quality, or when the source of supply is changed. If the results of the field tests are satisfactory and there is no change in the source, samples of the coarse aggregate need be sent to the Laboratory for check tests only as directed.

Collection of Samples of Coarse Aggregate

74. A composite sample for field tests on coarse aggregate delivered in cars should represent approximately 400 tons or less, the amount depending on the total daily shipments. To get the material for a sample, three channels -- one in the middle and one near each end of the car -- should be dug across the full width of the car and as deep as possible. The individual portions taken from each channel should weigh between 25 and 200 pounds. If the aggregate has become segregated into various sizes, the samples should be taken from those points where segregation exists, and all sizes should be included. The portions taken from the channels should be mixed thoroughly into a uniform composite sample.

A composite sample for field tests on coarse aggregate delivered by barge should represent approximately 400 tons. The barge should be divided into sections of the proper size, three channels should be dug in each section, and the procedure outlined for car sampling should be followed.

When coarse aggregate is delivered in trucks, a composite sample for field tests should represent 400 tons or less, the amount depending on daily shipments. Individual portions for a composite sample should be taken from pits dug at random, and they should be combined as described for car sampling. Each truck shipment should be kept separated so that it can be identified, and the material should not be put in a general stockpile until it has been tested and accepted.

Control of Segregation of Coarse Aggregate

75. When coarse aggregate is loaded into a car, barge, truck or dumped onto a stockpile, the different sizes tend to segregate. Because of careless handling, the larger pieces may find their way to the outside of a cone while smaller sizes remain at its peak. Segregation may be reduced by using baffles, or by moving the car, barge, or truck, while it is being loaded. Stockpile segregation can be eliminated if a stockpile is carefully built up and removed in 4-foot layers, as required by the Specifications. When coarse aggregate is segregated in a car, barge, or truck, the material can sometimes be unloaded so as to overcome this condition. If the resulting gradation complies with the Specifications, the material may be accepted. If it is obviously impossible to recombine the segregated portions, the material should be rejected.

The responsibilities of a Plant Inspector start when material arrives on the project and continue until the various materials are proportioned so that the mixtures meet all requirements of the Specifications. A Plant Inspector should realize that he has the important duties of controlling the unloading, stockpiling, and proportioning of the materials, as well as sampling and testing them. For instance, an Inspector may be very careful in sampling and testing the coarse aggregate, and the aggregate may have been found to be of excellent quality when it was delivered in the cars, barges, or trucks. However, coarse aggregate can segregate very easily while it is being handled. If segregated aggregate is used in proportioning concrete, the mixture placed in the structure may not be suitable for its purpose. The Inspector-in-Charge and the Construction Engineer will instruct and train Plant Inspectors so that they can maintain adequate control over all plant operations.

Checking Unit Weight of Coarse Aggregate

76. The unit weight of stone or gravel intended for use as coarse aggregate in concrete mixtures should be determined at least once a week. A change in unit weight indicates a change in the gradation and shapes of particles of aggregate. If the change in unit weight corresponds to a change in solid volume of more than 2 percent, consideration should be given to redesigning the concrete mix or correcting the gradation of the coarse aggregate. The Construction Engineer and the Materials Engineer must be told about the difference in weight before the concrete mix is redesigned.

Objective in Sampling Plastic Portland Cement Concrete

77. In order that the results of any test on concrete may be valuable, it is important to get a representative sample. Unless the test sample is taken properly, the test results will be misleading and useless.

Concrete is a mixture of coarse aggregate, fine aggregate, cement, and water. The solid particles range in size from very small to 1 or 2 inches, but they all are much heavier than water. When plastic concrete is discharged from a mixer or mixer truck, moves down a chute, or is dumped into forms, the small particles tend to sink to the bottom, so that more liquid material is left at the surface. The objective in sampling a batch of plastic concrete is to collect the sample in such a way that it will have the same proportions of coarse aggregate, fine aggregate, cement, and water as the entire batch. After the sample has been collected, care must be taken that no water is lost.

When mixed concrete is being discharged from a mixer or mixer truck, there is a general tendency for the concrete to segregate in such a way that the mixture issuing first has a higher proportion of mortar than the mixture discharged last. Concrete dumped from a mixer bucket in a pile usually has more coarse aggregate in the center of the pile. Concrete allowed to flow from the unbaffled end of a chute usually has more mortar in the concrete nearest the chute. If a truly representative sample of concrete is to be obtained and if the results of tests are to have real meaning, the effects of segregation must be overcome in taking the sample.

An excessive amount of segregation can be prevented by care in proportioning, mixing, transporting, placing, and compacting the concrete.

Equipment for Handling Samples

78. For any test of concrete, at least 1 cubic foot or about 150 pounds, will be needed. Some tests require as much as 4 cubic feet. Since the entire sample must be collected in one place for remixing, it is necessary to use some large container, that can be moved easily to the place at which the test is to be made. Usually the best container at the job site is a clean wheelbarrow or concrete buggy. Any material that has been left in the wheelbarrow or buggy should be removed. Then the barrow or buggy should be washed and rinsed out. Just before the sample is put in it, the inside should be wiped with a damp cloth or burlap so that no water will be added to, or removed from, the collected sample.

The best tool for collecting and handling concrete is a scoop with high sides. If a shovel is used, there is a tendency for some of the coarse aggregate to roll off. The concrete that is left on the shovel then has a larger proportion of mortar than the concrete in the batch. In some cases a clean bucket may be used to collect concrete flowing from a truck mixer or from a chute.

Procedure for Sampling Concrete

79. A composite sample of concrete taken from a truck mixer, agitator, or construction mixer of Type S should usually be collected in a clean wheelbarrow, concrete buggy, or bucket. Before the barrow or buggy is used, its inside should be clean and damp.

A sample may be obtained from a truck mixer or agitator by taking portions at three or more regular intervals during the discharge of the entire batch, but a portion must not be taken at the beginning or end of the discharge. A portion may be taken by repeatedly passing a small container through the entire discharge stream, or by diverting the entire stream so that it flows

directly into the barrow, buggy, or bucket. The rate of discharge of the batch should be regulated by controlling the rate at which the drum revolves, rather than the size of the gate opening.

A sample from a construction mixer should be taken from about the middle of the batch by passing a small container completely through the stream coming out of the mixer, or by diverting the entire stream so that it flows into the barrow, buggy, or bucket. Care must be taken not to hinder the flow from the mixer so as to cause the concrete to segregate.

The portions of the concrete to be combined into a composite sample must be carefully remixed with a shovel. Remixing should be continued only long enough to insure a uniform composite sample.

When concrete is mixed in a paving mixer of Type E, a composite sample representing an entire batch should be taken after it has been dumped on the subbase. Portions of concrete taken from at least five locations in the batch should be placed on a clean, smooth, hard surface, on which they should be carefully remixed with a shovel just enough to insure a uniform composite sample. If the portions are removed from the subbase with a shovel, care shoul be taken to prevent any loss of mortar or aggregates from the shovel while the concrete is being carried to the site selected for remixing.

When a composite sample is to be obtained from a receiving hopper, concrete bucket, or other container, the more suitable of the two procedures just described should be followed.

Not more than 15 minutes should elapse between the time any sample is collected and the beginning of the test. During this period, the sample must be protected from sunlight and the wind.

Slump of Concrete

80. The consistency of concrete, or its "workability" is indicated by a distance called it's "slump". The lower the slump of concrete, the stiffer the mixture. For the same proportions of cement, fine aggregate, and coarse aggregate, concrete with a low slump contains less mixing water than does high-slump concrete. Low-slump concrete is stronger and resists the effects of weather better. It also shrinks and cracks less while it hardens.

Low-slump concrete will not flow down a chute. Also, to get a dense mixture with smooth surfaces, low-slump concrete must be well spaded or vibrated in the forms. High-slump concrete will easily slide down a chute, and will flow readily into corners in the forms. Because of segregation, however, the large particles of aggregate tend to sink to the bottom, and too much water rises or "bleeds" to the surface. The concrete near the surface is therefore weak. If high-slump concrete is used in a pavement, tire chains on cars will wear the pavement surface rapidly.

The best slump for concrete depends on the purpose for which the concrete is to be used. Specifications require that the slump of concrete for a particular use be between certain limits. If the slump is measured in accordance with the Standard Procedure, concrete that has a slump within the specified range can be properly placed and compacted with the right equipment. Also, the concrete will have sufficient strength and will last a long time.

Frequent slump tests should be made on concrete used on a project. If the measured slump is too high or too low, the Inspector on the job should immediately notify the Plant Inspector. A large change in slump is usually caused by changes in the moisture contents of the aggregates. If there have been such changes, adjusting the amount of water added at the mixer will usually bring the slump between the specified limits. For the short period of time before the results of tests for moisture content are available, the Inspector may call for an increase or decrease in the water per batch to obtain the desired slump. A new Batcher-Mixer Slip should then be issued by the Plant Inspector.

Equipment Needed for Slump Test

81. The test specimen for a slump test is formed in a tapered mold made of 16-gage sheet metal. The mold, which is usually called a slump cone, is 12 inches high, 4 inches in diameter at the top, and 8 inches in diameter at the bottom. It is open at top and bottom, and must have handles and foot pieces. The slump cone must be cleaned by washing after each use. At the end of the day, it may be lightly oiled. If concrete hardens on it, or if it becomes bent or battered, the test results will be false.

The concrete should be put in the slump cone with a metal scoop having a rounded bottom. A trowel or shovel should not be used for this purpose. The scoop may be 3-1/2 to 4-1/2 inches wide, 6 to 7-1/2 inches long, and 2-1/2 to 3-1/2 inches high, and it should have a handle 5 or 6 inches long. It must be kept clean by washing with water after each use.

Concrete must be tamped in the cone with a metal rod 2 feet long and 5/8 inch in diameter. The end that penetrates the concrete must have a rounded point. A rod with a square point must not be used, because it would push the large particles of aggregate toward the bottom of the mold and the test result would be wrong.

When the test is being made, the slump cone must be placed on a smooth, flat, moist platform. A metal pan or a flat metal plate about 1-1/2 to 2 feet wide and 2-1/2 feet long is best for this purpose. A smooth piece of plywood or a form panel may be used, but a rough board or a concrete surface is not suitable.

To make the slump test properly, it is usually necessary to handle the concrete with the hands. If the hands are left bare, the skin may chap or crack. The hands may be protected with cheap working gloves, made of cotton with a rubberized surface.

A folding rule, a ruler, or a scale, which is at least 8 inches long and is marked off in inches and 1/4 inches, is needed to measure the slump.

Filling Slump Cone

82. The sample of concrete used for the slump test must be representative of the batch or lot from which it was taken. Instructions for collecting a sample are given in Section 79 of this Manual. It is best to collect portions of the sample in a wheelbarrow, mix them well, and then fill the slump cone from the wheelbarrow. It is difficult to fill the slump cone properly with

concrete from a small container, such as a bucket. Everything used to hold, mix or transfer the concrete must be clean and damp, so that no water will be lost from the concrete.

The slump test should be made in a place that is out of the way of other operations and is free from vibration. The platform on which the slump test will be made should be set on a firm support so that it will be level and will not rock during the test.

The part of the platform that will be under the slump cone and the inside of the slump cone should be wiped with a damp cloth. Then the cone is put on the platform with its large end down, and the person making the test places his feet on the foot pieces of the cone to hold it down firmly until the end of the test. Everything needed for the test should be within reach so that he will not have to step off the foot pieces. See Picture No. 1.

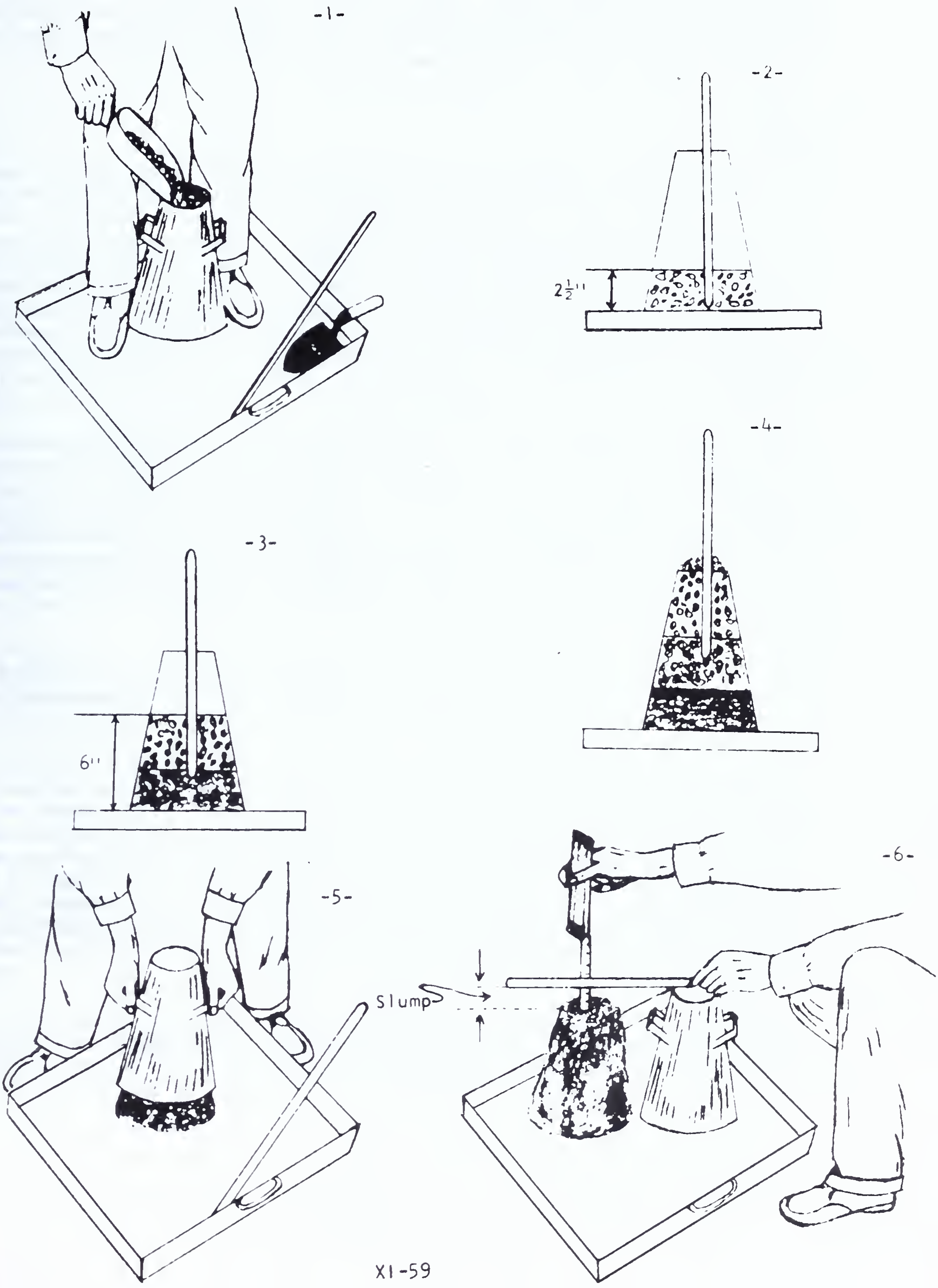
The concrete is put in the cone in three layers, each of which contains about one-third of the concrete. As soon as the concrete for a layer is in the cone, that layer should be tamped 25 times with the rounded end of the rod. The cone should be filled as quickly as possible, and there should be no long pause after a layer has been tamped. Not more than 1-1/2 minutes should elapse between the start of the filling process and the removal of the cone.

When concrete is taken from the wheelbarrow, the scoop should be pushed deeply into the concrete and brought out overflowing. The left hand should be held at one side of the top of the cone to guide the concrete into the cone from the scoop held on the opposite side. After the scoop has been partly emptied, the scoop should be moved to the left hand and the right hand should be used as a guide. Each time the scoop is refilled, the concrete should be put into the cone from a different position. The depth of the first layer should be about 2-1/2 inches. To tamp this layer, the rod should penetrate all the way to the bottom of the cone but should not strike a sharp blow on the platform. See Picture No. 2 Each stroke of the rod should be in a different place so that the larger particles of aggregate are distributed uniformly and the concrete is compacted uniformly.

The second layer of concrete is placed in the cone in the manner just described for the bottom layer. The total depth of the lower two layers should be about 6 inches, or the top of the second layer should be about 6 inches below the top of the mold. The second layer should be rodded 25 times in different places. The rod should just penetrate into the bottom layer. See Picture No. 3.

The final steps in filling the cone are as follows: Enough concrete is added to cause an overflow, and the top layer is rodded 25 times in different places. The rod should just penetrate into the second layer. See Picture No. 4 Then the extra concrete is scraped off by holding the rod or a short straightedge flat against the top of the cone and sliding it across the cone with a sawing motion. If necessary the scraping operation should be repeated.

The Right Way To Make a Slump Test



To make sure that the concrete in each layer is rodded to the proper depth, rings may be filed on the surface of the rod at distances of 12, 10, and 6-1/2 inches from the rounded point. The rod should be grasped so that the heel of the hand is at the right mark for the layer being rodded. When the hand hits the top of the cone during rodding, the rounded point of the rod will be at the right depth. A glove should be worn so that the hand will not be cut.

Measuring Slump

83. As soon as the cone has been filled and the excess concrete has been scraped off the top, the person making the test should lean forward and press down on the top of the mold with one hand so as to hold it firmly in place on the platform. While still holding the cone in this way, he should get off the foot pieces and use a trowel to remove all spilled concrete from a space at least 8 inches wide around the base of the cone. As he goes around the cone, he may change the position of his hand but should not allow the cone to move in any way. Then, during a period of about 5 seconds, he should remove the cone from the concrete by taking hold of the handles and pulling it straight up, as if he were lefting a heavy weight, at the same time twisting it back and forth slightly. See Picture No. 5.

If the concrete slumps uniformly, the slump should be measured in the following way: The cone is set on its large end alongside the slumped concrete; the rod or a short straightedge is laid on top of the cone so that it is level and extends over the center of the slumped concrete; and the distance taken as the slump is measured from the bottom of the rod or straightedge to a point on the surface of the slumped concrete. This point must be directly over a point that was on the axis* or centerline of the cone while it was being filled. The slump is recorded to the nearest 1/4 inch. See Picture No. 6.

After the slump has been measured, the slumped concrete should be tapped with the tamping rod. If the concrete settles down uniformly, the concrete should be described in the report as plastic. If it falls away or separates, it should be described as harsh.

If the concrete tips or falls away to one side when the cone is removed, the slumped concrete should be thrown away and another test sample should be made. This time greater care should be taken to get the aggregate uniformly distributed in the cone. If the concrete in the second test sample falls away on one side, the concrete is probably too harsh (not plastic enough) to permit the consistency to be measured by the slump test. In such a case, the result of the slump test has no meaning and no slump should be reported. Instead, the concrete should be described as being dry, non-plastic; or wet, non-plastic.

In any case, the concrete used for the slump test should be thrown away. It should not be used again for making other tests. All equipment used in the slump test should be cleaned immediately by washing it with water.

Entrained Air in Plastic Concrete

84. Air is entrained in plastic portland cement concrete in the form of very small bubbles by adding an air-entraining agent* to the cement during its manufacture or by adding an air-entraining agent to the concrete during the mixing process. The air bubbles are distributed throughout the mortar in the concrete. Their presence increases the resistance of the concrete to the effects of freezing and thawing and to the effects of chemicals used on pavements for melting ice. However, since the entrained air reduces the strength of the concrete, the right percent should be used. It is therefore necessary to measure the air content of the concrete frequently and to make sure that the percent of entrained air is between the limits given in the Specifications.

For most concrete mixes, the percent of air is measured by the pressure method. For concrete mixes in which the coarse aggregate is slag or other material with large pores the pressure method would measure not only the entrained air but also the air in the pores in the aggregate, so the volume method is used. Instructions for collecting a sample for a test for entrained air are given in Section 79 of this Manual.

Equipment for Pressure Method

85. The equipment needed in the test for determining the percent of entrained air by the pressure method consists of the following items: a suitable air meter (an Acme Air Meter is furnished by the Department for this purpose); a mallet that weighs about 1/2 pound and has a rubber head; a tamping rod, like that used for the slump test, which is 5/8 inch in diameter and 2 feet long and has a rounded point; a metal strike-off bar with a straight edge; a water container having a capacity of 1 gallon; a trowel; and wiping rags or paper towels.

An Acme Air Meter has two main parts, which are held togéther, one above the other, by clamps. The bottom part is the container for the concrete and has a wide flange with a milled edge around its top. The upper part consists chiefly of a water column and has on its side a glass gage graduated in tenths from 0 to 7 percent. The air meter must be kept clean, and care must be taken to prevent damage to it while it is being handled or when it has been set aside. Every air meter is calibrated* at the factory. However, a meter should be checked once in a while in the following way: The check cylinder, which is provided with the meter, is placed in the bottom part of the meter with the open end down. The container is filled with water, the top part is clamped on, and this part is filled with water to the arrow mark. When a pressure of 15 psi (pounds per square inch) is produced by the air pump, the reading on the glass gage should not be more than 0.1 percent above or below the figure appearing in the instructions for the particular meter. If the difference is too great, the meter should not be used until a new pressure gage has been installed.

Since the volumes of different air meters vary slightly, any meter must be calibrated by using the check cylinder furnished with it. Each air meter and its check cylinder are stamped with the same number.

Making Test for Air Content by Pressure Method

86. To start the test for measuring the air content of a well-mixed composite sample of concrete, the top part of the air meter is removed, and the bottom part is filled with concrete in three layers. The concrete in each layer is placed into the meter with the scoop from different directions. As soon as the meter is about one-third full, the concrete is compacted by using the tamping rod 25 times in different places, as described for filling the slump cone. Then the sides of the meter below the surface of the concrete are tapped lightly with the mallet 10 to 15 times, until the holes left by the tamping rod disappear and there are no large air bubbles on the surface of the concrete. The concrete in the second layer is placed in the meter, rodded, and tapped in a samilar manner. When the third layer is placed, the bottom part of the meter is filled to overflowing. After the concrete in this layer has been compacted by rodding and tapping, the surface is struck off even with the top edge of the bottom part of the meter by sliding the metal straightedge across the top flange with a sawing motion as much as necessary.

Now the milled edge on the bottom part of the meter should be cleaned thoroughly with a rag or paper towel, and the underside of the top part should also be cleaned so that the two parts will join tightly enough to make an air tight seal. The top part of the meter is then set on the bottom part and fastened to it by tightening first one clamp and then another, a little at a time, so that there is the same force on each clamp. With the bottom pet cock closed and the top pet cock open, the screw plug in the top of the meter is removed, and water is poured into the funnel at the top of the meter until it runs out of the top pet cock. The top pet cock is then closed, and the upper part of the meter is tapped 5 or 6 times to get rid of any air bubbles in the water. The bottom pet cock is opened, and water is allowed to escape, until the water level in the glass gage is at the zero mark. The bottom pet cock is closed, the screw plug in the funnel is replaced and tightened.

The air pump, which is clamped to the side of the meter, is attached to the air valve, and air is pumped into the meter until the reading on the air gage is exactly 15 psi. This reading should then stay the same after pumping has been stopped. If it drops, the test must be made over again, and more care must be taken to get the joint between the two parts of the meter perfectly clean. If the air-gage reading stays at exactly 15 psi, the glass gage is read at the surface of the water.

At this stage in the test, the sides of the lower part of the meter should be again tapped about 15 times with the mallet, and the reading of the glass gage should be checked. If it has dropped, the air pressure is brought back up to 15 psi, and the sides of the meter are tapped again. These operations are repeated until there is no change in water level or air pressure with continued tapping. The final reading of the glass gage at the water surface, taken to the nearest 0.1 percent, is reported as the percent entrained air in the concrete.

If the result of the test does not fall between the limits in the Specifications, the Inspector-in-Charge or the Assistant District Construction Engineer should be notified.

Equipment for Volume Method

87. When the percent of entrained air in plastic concrete is to be determined by the volume method, the following equipment is needed: a suitable air meter (a Roll-a-Meter is furnished by the Department); a funnel with a baffle at the bottom, which is supplied with the meter; a mallet that weighs about 1/2 pound and has a rubber head; a tamping rod, which is 5/8 inch in diameter and has a rounded point and which is supplied with the meter; a metal strike-off bar with a straight edge; a water container having a capacity of 1 gallon; and wiping rags or paper towels.

A Roll-a-Meter has two main parts, which are held together, one above the other, by clamps. The bottom part is the container for the concrete and has a milled edge around its top. The upper part consists of a water column and has on its side a glass gage graduated in tenths from 0 to 8 percent. The air meter must be kept clean, and care must be taken to prevent damage to it while it is being handled or when it has been set aside.

Test for Air Content by Volume Method

88. In the test for the percent of entrained air by the volume method, the top part of the air meter is removed and the bottom part is filled with concrete in three layers as described in Section 86 for the bottom part of the Acme Air Meter. After the bottom part of the meter has been filled to overflowing by the concrete of the third layer, and the concrete in this layer has been compacted by rodding and tapping, the surface is struck off even with the top of the bottom part of the meter by sliding the metal straightedge across the top flange with a sawing motion as much as necessary.

Now the milled edge on the bottom part of the meter should be cleaned thoroughly with a rag or paper towel, and the underside of the top part should also be cleaned so that the two parts will join enough to make an air tight seal. The top part of the meter is then set on the bottom part, and clamped to it. Water is poured into the top part slowly through the baffle-bottom funnel, so that the sample will not be disturbed and air will not be released. When water rises up into the glass neck, the funnel should be removed, and water should be added to the zero mark. Then the top cap is put on.

Next the meter should be turned upside down and shaken until the concrete settles free from the base. Then the concrete should be mixed into the water by rolling and rocking the meter on a flat surface with the neck slightly higher than the body, until all the air rises to the top. At this time the meter is set upright and jarred lightly on a flat surface to cause air bubbles accompanied by some foam to rise to the surface of the water in the neck. After the meter has been jarred continuously for a while, it should be allowed to stand, except for occasional light agitation, until no more air bubbles rise. This operation may take 3 to 5 minutes.

The foam may be condensed, if necessary,by adding 23 cc of rubbing alcohol from a special brass cup, provided with each meter, and stirring this in. The gage should then be read. If alcohol is used to condense the foam, 1 percent should be added to the gage reading to obtain the correct percentage of entrained air.

The result of the test should be checked by again turning the meter upside down and repeating the shaking, rolling, and jarring. If any more air is removed, the percentage of air shown by the gage reading will be greater. This higher value should be recorded in place of the first result.

Concrete Beams for Flexural Strength Tests

89. One way of measuring the strength of hardened concrete at a certain age is by testing a beam of standard size made of the concrete. A standard beam is 6 inches wide, 8 inches deep, and 22 inches long. The concrete needed for one beam has a volume of about 0.6 cubic foot and weighs about 92 pounds. Four beams should usually be made from each composite sample of the concrete. Tests for slump and air content should also be made on parts of the same composite sample. The total volume of a composite sample needed for four test beams, one test for slump, and one test for air content is at least 3 cubic feet.

Beam tests are made on concrete used in a base course, pavement, substructure or superstructure of a bridge, or other structure for such purposes as the following: to determine when a base course may be covered, when a pavement may be opened to traffic, when curing of a part of a bridge substructure is no longer necessary, or when the forms for a part of a bridge superstructure may be removed. Instructions for collecting a composite sample of concrete for beams are given in Section 79 of this Manual. The Assistant District Construction Engineer will prepare a copy of Form 458 C, showing the locations in a pavement or structure at which concrete for test beams should be sampled.

When a beam is to be tested, it is placed in the testing machine in a horizontal position on two supports, one near each end, with the 8-inch dimension vertical, and a force is applied to its top at a point midway between the supports. The flexural strength of the concrete is determined by what is called the modulus of rupture, which is computed from the dimensions of the beam and the force required to break it. The modulus of rupture is a stress measured in pounds per square inch, but there is no direct relationship between this stress and the compressive strength of the concrete.

Up to a certain point the modulus of rupture or the beam strength of concrete depends on the strength of the mortar that fills the spaces between the particles of coarse aggregate. Beyond this point, which changes with different aggregates, the modulus of rupture depends a great deal on the strength of the aggregate particles and on the bond between these particles and the mortar.

The force required to break a concrete beam depends a great deal on the rate at which the force is increased. For this reason, the Department makes all beam tests with a machine that increases the force at a certain uniform rate. Also, the strength of a beam which is tested dry will be different from that of one which has wet surfaces when tested. For this reason, a beam should always be tested in a moist condition; otherwise, there will be differences in the test results which are not caused by differences in the strength of the concrete.

Casting Beams

90. It is the duty of the Mixer Inspector to supervise the casting of test beams for pavement concrete. The Inspector-in-Charge on the project supervises the casting of beams of concrete for other structures.

The forms, or molds, for beams must be built of material that will not absorb water. They must be strongly built and assembled so that no part will bend or move while the mold is being filled with concrete. Each mold consists of a bottom piece, two side pieces, and two end pieces. The pieces are put together so that the side and end pieces may be removed as soon as the concrete hardens enough, and the beam can be left on the bottom piece during the entire curing period and until it is delivered to the test site. To permit the beam to be moved, an additional bottom piece is provided for each mold.

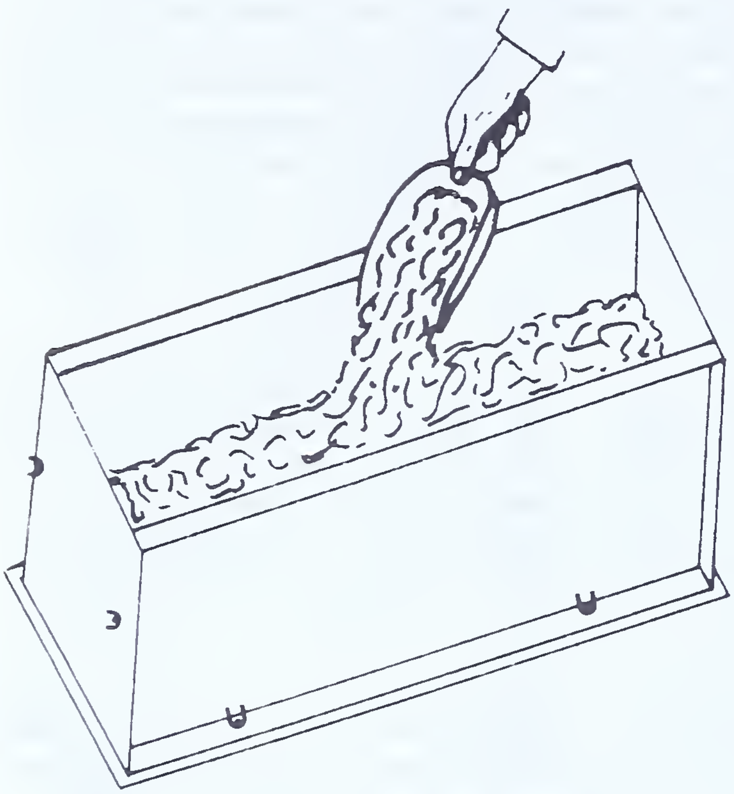
Four molds should be assembled for each test, either at the proportioning plant for delivery to the site of the test or at the site of the test.

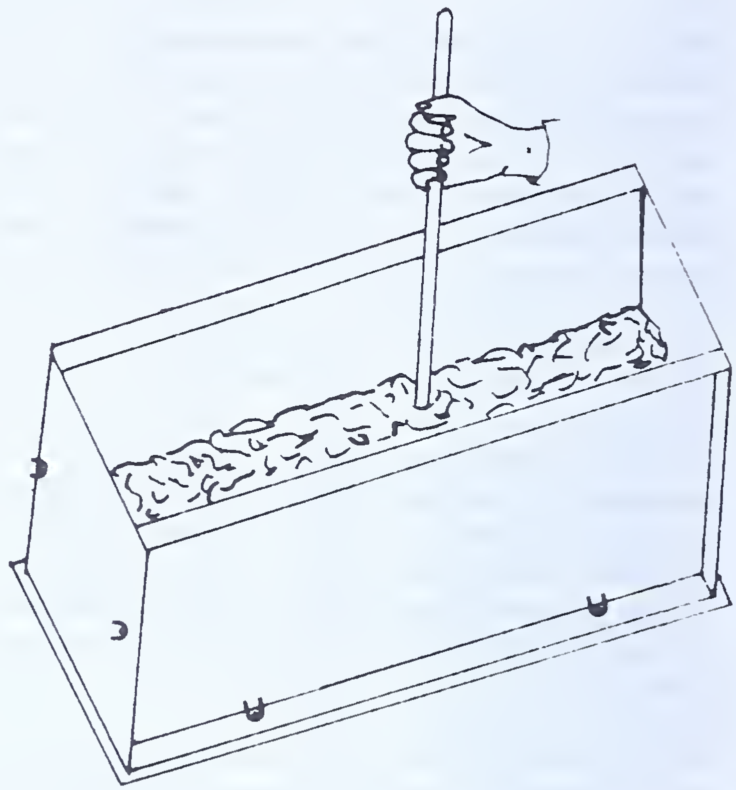
The Inspector must make sure that the inside dimensions of each assembled mold conform to the standard dimensions of the beam, and that the pieces are tightly clamped together and will remain firmly in position during the casting operation. The molds must be watertight. They should be lightly coated with oil before being used. After the oil has been put on, the inside of the mold should be wiped carefully with a piece of dry cotton waste or burlap to remove any excess oil.

When a mold is to be filled with concrete, it should be placed on a firm level surface at or near the point at which the beams are to be cured and out of the way of other operations. The composite sample of concrete, having a volume of about 3 cubic feet, should be brought to this location and mixed thoroughly. Tests for slump and air content should be made on parts of this sample before the beams are cast, and the concrete used in these tests should be thrown away. After the results of the slump and air tests have been recorded, the four molds for the beams should be filled with concrete from the sample in the following way:

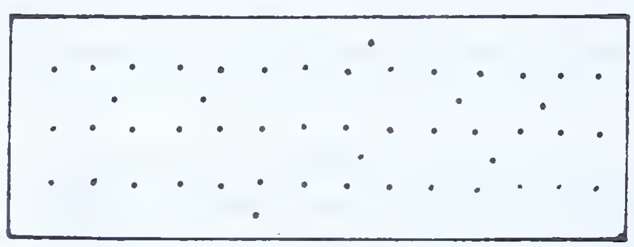
First each mold should be half-filled with concrete placed from a scoop so that the coarse aggregate will be distributed uniformly. The bottom layer in each mold should be tamped 50 times with the rounded end of the rod used for the slump test. The rod should penetrate the layer for its full depth, but should not strike a hard blow on the mold bottom. About 45 strokes of the rod should be distributed so that rows of three strokes evenly spaced across the form are located about 1-1/2 inches apart along the length of the form. The additional strokes needed to bring the total to exactly 50 should be located at random. With a mason's trowel, the concrete should be spaded along the sides and ends of the mold. The blade of the trowel should be held flat against the side of the mold, the blade pushed to the bottom, and the handle rocked away from the mold. These motions should be repeated all around the mold. The spading is finished by sliding the trowel around the inside of the mold with the blade flat against the mold and the point of the trowel touching the bottom of the mold.

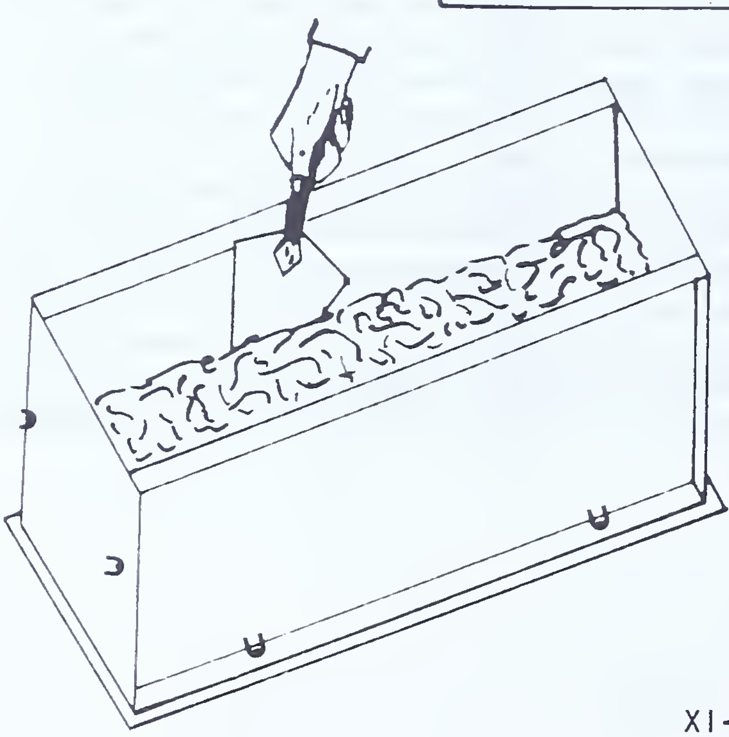
CASTING BEAMS FOR FLEXURAL STRENGTH TESTS

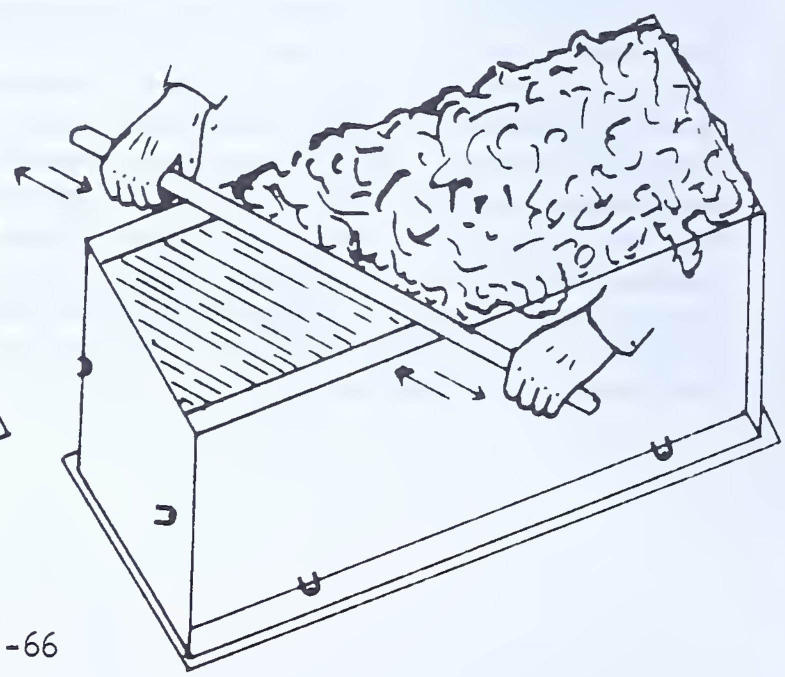




TAMPING PATTERN







After the bottom layer of concrete in each mold has been spaded, the four molds should be filled to overflowing, and the upper layer in each should be tamped 50 times with the rod. In this operation the rod should just penetrate the first layer (the point of the rod should be 4-1/2 to 5 inches below the top of the mold). The trowel should then be worked around the mold as before, but to a depth of only about 5 inches. The extra concrete should be struck off to the level of the top of the mold, and the surface finished quickly with a wood float. Care must be taken not to overfinish or to bring mortar to the top of the beam. Casting of the beams must be completed without stopping. Once placing of concrete in the molds is started, all tests must be completed not more than 30 minutes after the sample was taken.

The four test beams from one composite sample make up a set of beams, and all the sets for one pavement or one structure make up a series for the project. Each series may be identified by a letter, and each set in a series may be given a number. The numbering should start at 1 and continue in order. After the surface of each beam has been finished with the wood float, certain information must be scratched with a nail or other sharp-pointed tool. This marking should include the series letter, set number, station and date.

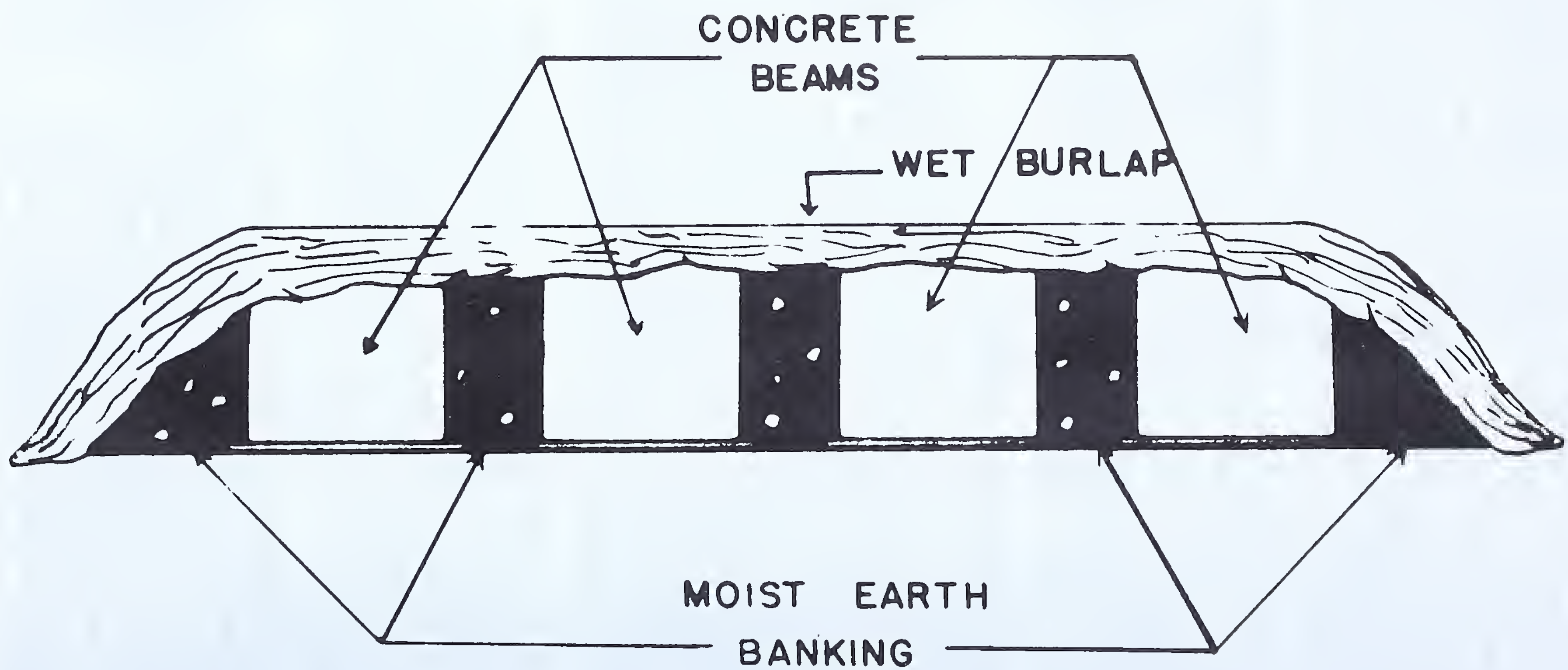
Curing Beams and Removing Molds

91. In general the concrete in beams for tests must be cured in exactly the same way, and at the same time, as is the concrete in the section of the pavement or the part of a structure represented by the test sample. For instance, the side and end pieces of the molds must be removed from beams made of pavement concrete at the time at which the side forms are removed from the pavement. The bottom piece of the beam mold should be left in place, and damp soil should be banked against the sides and ends of the beam. This soil should be kept damp, and the top surface of the beam should be cured in the same way as is the pavement. At the end of the curing period for the pavement, the beams should be left in place with their top surfaces exposed to the weather, just as the pavement surface is, until picked up for testing.

When beams are made from a sample of concrete used in a structure, they should be covered with wet burlap for the first 24 hours. After 24 hours the side and end pieces of the molds should be removed, but the bottom pieces should be left in place. The top and sides of the beams are then covered with at least two thicknesses of saturated burlap or with saturated curing mats. As nearly as possible, the rest of the curing process should be the same as that used for the concrete in the part of the structure represented by the test beams.

When curing by blanket insulation is permitted, the molds are left on the beams during the full curing period. The beams are placed in or near the structure, at some point where they will have full advantage of the heat generated by the hydration of the cement in the concrete of the structure. They are covered completely with blanket insulation and with sufficient straw or hay to prevent loss of heat during the curing period. As an additional precaution, a waterproof tarpaulin is used as an overall covering. A record must be kept of the curing temperatures of the beams and the structure. These temperatures are reported with the beam tests.

CURING TEST BEAMS



Care in Storing and Moving Beams

92. Great care must be taken to prevent injury to the test beams before they are tested. At early ages the concrete may seem hard, but actually it does not have much strength. If a beam is lifted off the bottom piece too soon, the weight of the beam may cause cracks to form. These cracks may be too small to be seen, but will greatly reduce the strength of the beam when it is tested. A beam should always be left in position on the bottom piece of the mold until it is removed at the location of the testing machine. A beam should always be kept upright and never turned to rest on its side.

Until a beam is about to be tested, it must always be moved by lifting the bottom piece of the mold on which it was cast, not by lifting the beam. The bed of the truck used to take the beams to the test site must be cushioned with several thicknesses of burlap,mats, straw, or similar material so that the beams will not be jarred. The beams, still in their original positions on the bottom pieces, should be carefully placed on this cushion so that they will be far enough apart to keep them from touching one another when the truck moves. Someone should ride in the truck body to protect the beams, and the truck should be driven slowly enough to prevent bumping or jarring of the beams. The Contractor or his representative, should be made to understand that it is to the Contractor's advantage to protect the beams.

Age of Beams at Time of Test

93. Unless otherwise instructed, beams are to be tested at the ages given in Table VII. Type B or Type C cement is normal strength cement. Type D cement is high-early-strength cement.

TABLE VII - Ages for Testing Beams

Class of Concrete	Age in Days: Type B or C Cement	Age in Days: Type D Cement	Minimum Strength, in Pounds Per Square Inch
Pavement mix	10 or 14	3 or 5	550
Base, Type A	10 or 14	3 or 5	500
Class AA concrete	7 or 10	3 or 5	500
Class A concrete	7 or 10	3 or 5	500
Class B concrete	7 or 10	3 or 5	450
Base, Type B	10 or 14	3 or 5	400

At the earlier of the two ages shown in Table VII, only two of the four beams usually cast from a composite sample of concrete are taken to the site of the strength test, and tested. The other two are left near the pavement or structure, under the same conditions of curing and exposure. If the average strength of the first two beams tested is above the minimum given in Table VII, the remaining two beams need not be tested. If the strength of the first two beams is below the required minimum, curing of the other two beams must be

continued until the later age in Table VII is reached, and these beams are then taken to the test site and tested for strength. If considered necessary by the Department or requested by the Contractor, additional beams may be cast for testing at ages later than those shown in Table VII.

Arrangements for Testing Beams

94. Beams are tested in a Rainhart Flexural Testing Machine. The Materials Engineer and the Construction Engineer will select the place at which the testing machine is set up. One testing site may be selected to serve two or more projects, if it is near enough to each project.

The machine must be kept in a clean, weather-tight building, which can be heated so that the tests are never made at a temperature below 60 degrees F. Only persons thoroughly trained in the operation of the machine and completely familiar with the procedure in making flexural tests are permitted to test beams and report the results. They are responsible for keeping the testing machine in good working order and seeing to it that its surroundings are clean and neat at all times. The Materials Engineer and the Assistant Construction Engineer should inspect each active test site often and make sure that the equipment is in good condition and the persons assigned to testing are competent. Instructions for keeping a Rainhart Flexural Testing Machine in good condition follow:

The machine must be supported on a platform of convenient height on which it can be kept firm and level during the tests. The cover of the testing machine must not be used as a platform. The machine must be covered when not in use.

The pressure recorder on the machine should be checked two or three times a year by the Materials Engineer with a field calibrating unit (No. 415-FC). The recorder should also be checked whenever it does not seem to be working properly. To assure the accuracy of the No. 415-FC unit, it must be checked in the Laboratory against a dead-weight tester at least once a year. For this routine checking, the No. 415-FC unit should be sent to the Laboratory during the winter months. After the necessary adjustments are made, it is returned to the District Materials Engineer.

The level of the hydraulic fluid in the reservoir on the testing machine should be checked to make certain that it stays within 1 inch of the top of the reservoir. A toothed washer, which is sandwiched between two flat washers, must always be in place above the reservoir cap to provide an air vent for the reservoir. Only No. 4 Rainhart hydraulic fluid, which is supplied by the Laboratory, should be used in the machine's hydraulic system. This oil has been especially compounded for minimum friction in the system and maximum life of the packing. The hydraulic system must be free from leaks when tests are made.

The point of the recording pen should be thoroughly cleaned with alcohol from time to time. To give accurate readings, the pen point should merely touch the recording chart. If the point drags or hangs on the chart, the condition can be corrected by bending the pen arm a little. Recording ink will be supplied by the Laboratory. No other ink should be used, because poor ink may corrode the pen point and interfere with its action. The position of the pen point at the beginning of the spiral should be checked. If an adjustment is necessary, it can be made with the micrometer screw on the pen arm.

Testing Beams for Flexural Strength

95. The Rainhart Flexural Testing Machine is used for determining the strength of a test beam in the following way: The chart drive is fully wound, and a No. 12218 recording chart is set in position by raising the arm that lifts the pen, putting the chart on the center hub, and securing it in place by tightening the hub knob. If the pen requires ink, not more than one drop should be placed on the point. In case the ink does not flow properly, the pen point should be cleaned and moistened slightly before it is re-inked. The progress of the recording chart should be checked by noting whether it moves over one-minute division in exactly 60 seconds. If there is any variation from this speed, the variation must be reported to the District Materials Engineer. The operator of the machine should never attempt to stop the chart drive, but should let it run down.

Now the control valve is closed by turning it clockwise, and the loading head is raised about 1/2 inch by operating the lever-type pump. If the pen point is not exactly at the zero line on the chart at this time, it must be brought to this point by adjusting the micrometer screw in the pen arm, which permits vertical adjustment of the pen. The control valve should be opened until the loading head reaches the bottom of its range, and should then be closed.

The beam to be tested is now removed from the bottom piece of the mold and is placed in the testing machine with its top side down. The beam should be inserted from the right-hand side of the machine, and the catcher arm should be used as an aid in sliding the beam into position. The beam must be centered accurately, both longitudinally and transversely, with respect to the four corner posts and the three strap-type bearings. To secure the beam in the machine, the knobs of the four corner posts are tightened moderately, but uniformly, so that the crosshead bearings remain as nearly level as possible. For very small beam twists, the pivotal action of the top crossheads and the bottom loading head allows these parts to become adjusted automatically.

With the control valve closed tightly, a slight preliminary load is applied to the beam with the lever-type pump. Then the remaining test load is applied by rotating the handwheel of the rotary pump. The speed of loading must be carefully controlled by always keeping the recording pen within the spiral loading track on the chart. If the rotation of the wheel stops, further rotation should not be forced, but its direction should be quickly and smoothly reversed to continue the loading until the beam breaks. Two beams are tested with one chart, and the total load required to break each beam is recorded on the chart.

When a beam breaks, the control valve should be opened one full turn to allow the loading head to return to its original position. Then the control valve is closed, the beam sections are taken out, and fragments of concrete are removed from the machine. Also, after the total load required to break the beam has been recorded on the chart, the average width and depth of the beam should be measured at a point as near the line of fracture as possible, and these actual measurements should be recorded on the chart. The dimensions of a beam should never be reported as 6 and 8 inches if either differs from the standard by as much as 0.1 inch.

Computing Modulus of Rupture

96. Although every effort should be made to cast beams with a uniform cross section 6 inches wide and 8 inches deep, there are often slight variations in one or both of these dimensions. Whatever the actual dimensions of the cross section may be, the modulus of rupture can be computed by multiplying the total test load required to break the beam by the proper factor given in Table VIII. For example, if the measured dimensions of a beam after it broke were 6.0 inches and 8.0 inches and the test load that broke the beam was 8600 pounds, the modulus of rupture of the concrete was 8600 x 0.0703 = 605 psi. Similarly, if the measured dimensions were 6.1 and 8.2 inches and the breaking load was 8700 pounds, the modulus of rupture was 8700 x 0.0658 = 572 psi.

Reporting Results of Flexural Tests

97. When test beams are cast, the Inspector-in-Charge prepares four copies of Form 458-A for each test (two, four, or more beams). He should fill in all the information necessary to complete the Form, except the actual test load. All four of the copies are sent with the beams to the person assigned to perform the test.

The information requested on Form 458-A for portland cement includes the number of the manufacturer's bin from which the cement used in the beams was taken. The gradation of the fine and coarse aggregates shown on Form 458-A should represent the average, or typical, gradations of the aggregates being used at the time the beams are cast. They should not be the averaged gradations of the aggregates for the whole day.

When the person who performs the flexural test fills in the information requested on Recording Chart No. 12218, he uses data shown on Form 458-A and results obtained in the test. He must also complete Form 458-A by filling in the requested test data. Examples of a properly completed Recording Chart No. 12218 and a Form 458-A are shown here.

As soon as the beams have been tested, the person who made the test should send copies of the completed Form 458-A and the Recording to the proper places. The original and one other copy of Form 458-A and also the Recording Chart are sent to the District Office and marked for the attention of the District Materials Engineer. One copy of Form 458-A is returned to the Inspector-in-Charge. One copy of Form 458-A is kept in a reference file at the site of the test until the project is completed. This copy is then sent to the Inspector-in-Charge to become part of the project file.

The District Materials Engineer, after consulting the District Construction Engineer, will notify the District Engineer when the curing of the concrete in a pavement or structure may be stopped, and when loads may be permitted on the pavement or structure. When the District Engineer gets this information, he will have four copies of Form 458-B prepared for his signature. On this Form for a pavement are shown the recommended date for opening the pavement to traffic and the maximum loads permitted on it. Similar information is shown on the Form for a structure.

TABLE VIII - Factors for Finding Modulus of Rupture

Beam Depth, in Inches	Beam Width, in Inches										
	5.5	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5
7.5	.0873	.0857	.0842	.0828	.0814	.0800	.0787	.0774	.0762	.0750	.0738
7.6	.0850	.0835	.0820	.0806	.0792	.0779	.0766	.0754	.0742	.0730	.0719
7.7	.0828	.0813	.0799	.0785	.0772	.0759	.0747	.0735	.0723	.0711	.0701
7.8	.0807	.0792	.0778	.0765	.0752	.0740	.0728	.0716	.0704	.0693	.0683
7.9	.0787	.0772	.0759	.0746	.0733	.0721	.0709	.0698	.0687	.0676	.0666
8.0	.0767	.0753	.0740	.0727	.0715	.0703	.0692	.0681	.0670	.0659	.0649
8.1	.0748	.0735	.0722	.0710	.0698	.0686	.0675	.0664	.0653	.0643	.0633
8.2	.0730	.0717	.0705	.0693	.0681	.0669	.0658	.0647	.0637	.0627	.0618
8.3	.0713	.0700	.0688	.0676	.0664	.0653	.0642	.0632	.0622	.0612	.0603
8.4	.0696	.0683	.0671	.0660	.0649	.0638	.0627	.0617	.0607	.0598	.0589
8.5	.0679	.0667	.0655	.0644	.0633	.0623	.0613	.0603	.0593	.0584	.0575

If either beam dimension falls outside the limits given in Table VIII, the modulus of rupture can be calculated as follows:

$$R = \frac{3 \times P \times L}{2 \times b \times d \times d}$$

where R = modulus of rupture, in pounds per square inch
P = maximum applied load indicated on pressure recorder, in pounds
L = distance between supports, in inches = 18
b = average width of beam, in inches
d = average depth of beam, in inches

Form 458-A
Rev 4-61
COMMONWEALTH OF PENNSYLVANIA
Department of Highways
Testing and Research

FLEXURAL STRENGTH
OF
PORTLAND CEMENT CONCRETE

D-14
SERIES NO

Concrete Placed in - Reinforced Concrete Pavement
Route No. 189 Appl. Sec. 10 County Armstrong
Contractor A. B. White Construction Co. Station Moulded 21+50
Pavement Cross Section Center 9" Edge 9" Width 12'
Date Moulded 5-9-55 Weather Cloudy Temperature 60 degrees F.
Slump 1 3/8" Entrained Air 4.5% Mix Proportions 1-1.79-3.50
Curing (Give exact methods used) 72 hours, using approved curing paper

Material	Producer	Bin No.	Sand Tests			C. Aggr. Tests		
								2B
Portland Cement	Penn-Dixie	P.R.R. 121141	Pass	100	2.7	Pass	8-	1.
			"	50	21.1	"	4	2.
Fine Aggregate	Allegheny Sand & Gravel Co.		"	30	49.6	"	½	46.
			"	16	70.0	"	1"	94.
Stone ~~Gravel Slag~~	Green Stone Company		"	8	83.2	"	1½"	100.
			"	4	95.4	"	2"	
Water	Local: See Lab. No. AN-643		"	3/8	100.0	"	2½"	
Calcium Chloride		Spec. Gr.	F.M.					

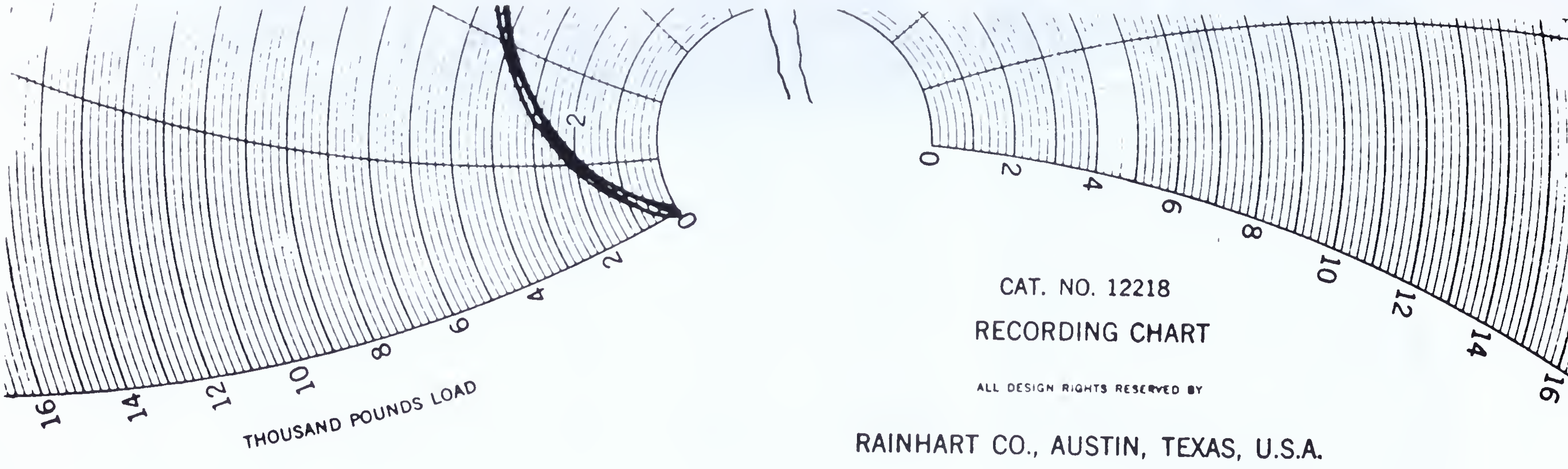
Strength Tests

Beam	Cross Section Dimension	Total Test Load Applied - Pounds: Age 10 Day	14 Day	Day	Factor	Flexural Strength - PSI: Age 10 Day	14 Day	Day
A	6"x 7 7/8"	430				536		
B	6"x 8"		490				580	
Aver.								
C	6 1/8"x 8"		490				568	
D	6 1/8"x 8 1/4"		510				562	
Aver.								
E								
F								
Aver.						536	570	

Date of Tests 5/19 Day 5/23 Day Day
Apparatus No. 10-0, (4)

Moulded by A. C. Jones Title Senior Inspector
Tested by P. P. Smith " Senior Inspector
Reported by C. O. Marks " Junior Inspector
Formula Used: Sr. = 90 + W_3, corrected for beam size

Recommendations:



FORM NO. ____

CONCRETE BEAM FLEXURAL STRENGTH TEST

CONCRETE BEAM NO. **A & B** FLEXURAL STRENGTH TEST FOR TYPE **Pavement** CONCRETE PLACED IN **East Bound Traffic Lane**

ROUTE **129** SECTION **1A** DISTRICT **8-0** COUNTY **Dauphin** CONTRACTOR **A. B. White Construction Co.**

STATION MOLDED **260+00** DATE MOLDED **June 8, 1961** WEATHER **Fair** TEMP. **88°**

SLUMP **1 3/4** in. PEN. ____ in. ENT. AIR **5½** % CURING **Burlap 24 hrs. - Paper 72 hrs.**

DATE TESTED **June 18, 1961** AGE **10** LOAD **A=8600 B=8700** lb. WIDTH **A=6.0 B=6.1** in. DEPTH **A=8.0 B=8.2** in.

FACTOR **A=.0703 B=.0658** FLEXURAL STRENGTH **A=605 B=572** psi SPECIFICATION **550** psi

REMARKS **Since beams A & B exceeded strength requirements, beams C & D were not tested.**

MOLDED BY **James Black** TITLE **Construction Insp. II**

TESTED BY **Louis Green** TITLE **Construction Insp. I**

SERIES NO. **1**

Concrete Cylinders for Compressive Strength Tests

98. Another way of measuring the strength of hardened concrete at a certain age is by finding the load required to crush a cylinder of standard size made of the concrete. It has been found that the best test results are obtained when the height of the cylinder is about twice its diameter. Test cylinders are 12 inches high and 6 inches in diameter. The concrete for one such cylinder has a volume of about 0.2 cubic foot and weighs 30 pounds. The molds in which the test cylinders are cast are generally made of metal. Cardboard molds may be used if they are entirely waterproofed with paraffin wax and the concrete cylinders are kept tightly covered. If a mold leaks or absorbs water, or if water evaporates from the top of the cylinder, the result of the test will not show the true strength of the concrete. The methods of casting, handling, and curing the test cylinder also have important effects on the test result. In order that the result of a test may have real meaning when compared with the results of other tests, the Standard Procedures for collecting a composite sample of the concrete and making and curing the cylinders used for tests must be followed exactly.

Cylinders are tested for either of two purposes. One is to determine the quality of the concrete. The other is to control the concreting operations on the job by finding out how rapidly concrete is gaining strength or how strong it is at a certain time. Test cylinders to be used for job control must be cured as nearly as possible under the conditions existing in the mass of concrete that they represent. For example, when a bridge deck is being constructed during cold weather, test cylinders made from concrete taken from the deck should not be stored in a warm place. The cold concrete in the bridge deck will not gain strength so rapidly as would the warm concrete in the test cylinders so stored. Its strength could be far below that of such test cylinders.

Equipment for Casting Cylinders

99. The equipment needed for casting test cylinders consists of suitable molds, a scoop and a tamping rod like those used for the slump test, and a curing box or casting platform.

The molds for casting test cylinders must have the right dimensions and must be watertight. If a mold is not made of metal, it must have an attached bottom. A paraffined cardboard mold should not be used if it has been bent out of shape while in storage or has had holes punched in it. Unless a mold has a tight-fitting cover, a glass or metal coverplate must be at hand to prevent evaporation of water from the concrete after the mold has been filled.

The only proper way of putting concrete into a mold for a test cylinder is with a scoop. Using a trowel or a shovel for this purpose will make the test results false. The mold should never be filled by holding it in a stream of concrete.

In any case, molds for test cylinders must be set on a firm level surface while they are being filled with concrete. Best results are obtained when test cylinders to be used for determining the quality of concrete are cast directly in a wooden curing box that has a hinged lid. The cylinders should

be kept at a temperature between 60 and 80 degrees F., and should be protected from accidental blows. When a curing box is used, a kerosene latern placed in the box during cool weather helps to keep the temperature up.

In warm weather, test cylinders for job control may be made on a level piece of plywood, or form panel, and the tops and sides of a group of cylinders may be kept covered by several thicknesses of wet burlap.

Procedure in Filling Molds

100. A composite sample of concrete for test cylinders must have a volume of at least 1 cubic foot. It is best collected in a clean wheelbarrow by one of the methods described in Section 79 of this Manual. As soon as the sample has been collected, it must be taken to the site at which the cylinders are to be cast, and there thoroughly remixed. Not more than 15 minutes should elapse between collection of the sample and casting of the test cylinders. During this period, the sample must be protected from sunlight and wind by a covering of moist burlap.

The curing box or platform must be located where it will be out of the way of other operations and entirely free from vibrations. The box bottom must be supported on a firm, smooth, level surface. The required number of cylinder molds to be filled at one time should be placed on the casting surface about 2 inches apart.

When concrete is being placed into a mold from the scoop, the scoop should be moved around the top edge of the mold as the concrete slides from it. Each time it is emptied, the scoop should be refilled to overflowing. Also, the concrete should enter the mold from different directions so that there will be the same amount of coarse aggregate on all sides of the sample.

A mold should be filled in three equal layers. The first layer should have a depth of 4 inches. The concrete in this layer should be distributed by a circular motion of the tamping rod, and should then be tamped 25 times with the round end of the tamping rod. The point of the rod should reach to the bottom of the mold but should not strike a hard blow on the supporting surface. If the last strokes of the tamping rod leave holes in the concrete, these holes should be closed by tapping the outside of the mold gently with the side of the tamping rod.

After the bottom layer in all the molds of a group has been rodded, a second 4-inch layer of concrete is placed in them and compacted. When this layer is rodded, the end of the tamping rod should just penetrate into the layer beneath. The top layer should fill the mold to overflowing. After this layer is rodded, the extra concrete is struck off with a sawing motion of the rod or a short straightedge, such as a piece of board. Care must be taken not to overwork the concrete. The surface of the concrete must be fairly smooth with no large holes, and must be exactly level and even with the top of the mold. It is not necessary to have a trowel finish.

After the cylinder molds have been filled and the extra concrete has been screeded off the top, the molds must not be moved or jarred until the concrete has hardened. If they are, there will be what is called "water gain". Since the cement and the aggregates in the concrete are much heavier than the water, the solid particles tend to settle and the water tends to rise to the top. In some concrete mixes the cement paste may be forced away from the bottoms of the aggregate particles and be replaced by a film of water. This water gain is speeded up by any kind of vibration. If the test cylinders are moved or jarred too soon, there will be more water gain in them than in the large mass of concrete they are supposed to represent, and the test results will be lower than they should be.

<u>Early Curing of Test Cylinders</u>

101. As soon as the tops of the cylinders in the molds have been made smooth, the covers must be put on the molds, or the molds must be covered with glass or metal plates, to prevent evaporation of water from the cylinders. There is only a small amount of water in a test cylinder. If any of it is lost, the test results will be false.

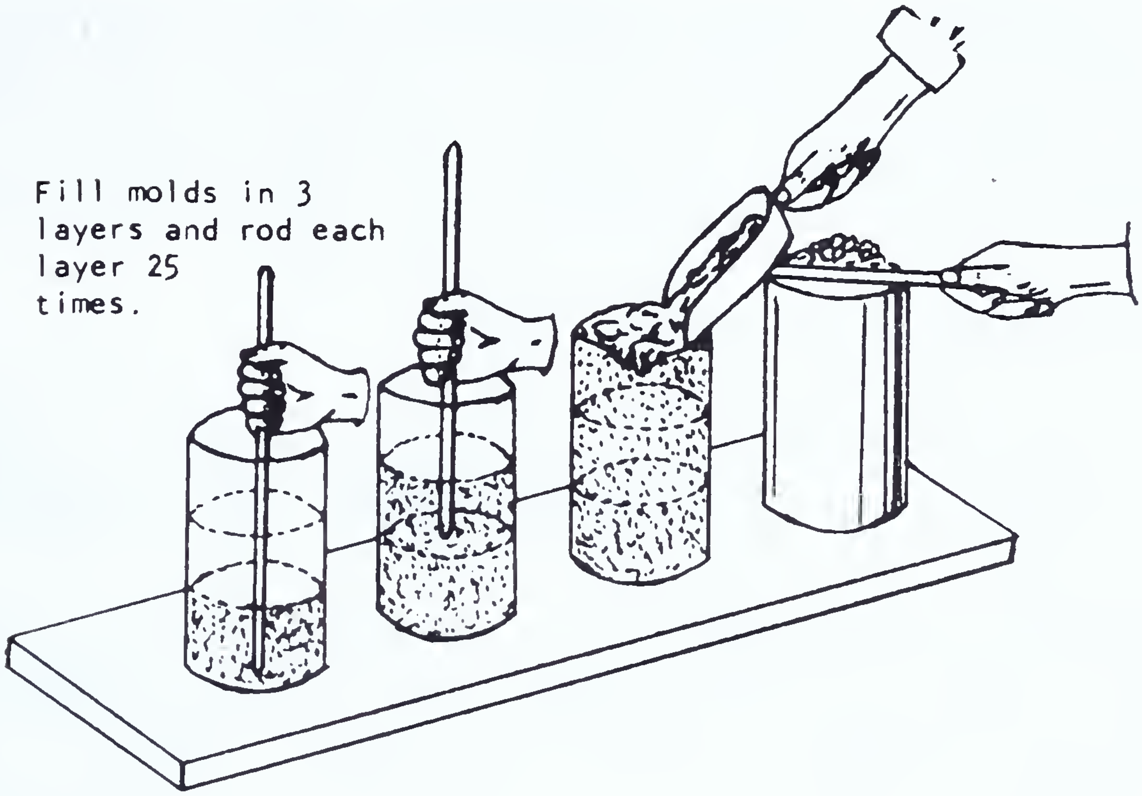
As soon as the molds are covered, they must be protected from the sun and extremes of hot or cold weather. This is best done by casting the cylinders in a curing box which can be covered. If the cylinders are cast on a platform in warm weather, they must be covered and draped with four or five layers of wet burlap. In any case, the cylinders must be kept moist and at a temperature between 60 and 80 degrees F. for the first 24 hours. At the end of about 24 hours, cylinders made for job control may be moved if handled carefully. They should be removed from the molds and put where they will be at the same temperature as the concrete in the structure as near as possible to the point at which the sample was collected. Cylinders made for determining the quality of the concrete should be moved very carefully to a place where they will not be damaged. They must be kept moist and at a temperature between 60 and 80 degrees F. until sent to the Laboratory, where they will be put under standard curing conditions.

<u>Handling and Shipping Test Cylinders</u>

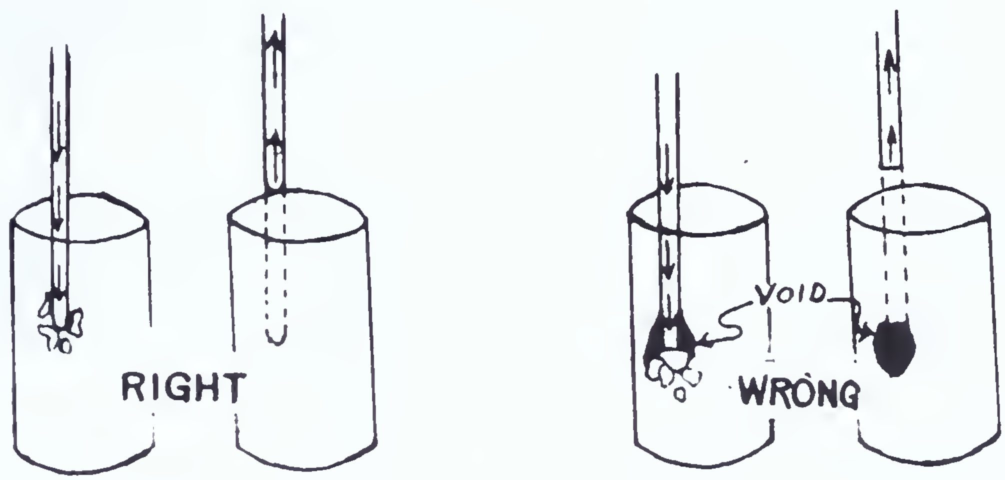
102. Test cylinders being moved to a testing site must not be thrown loose into the back of a car or pickup truck. They should be packed in a box, with sawdust, crumpled paper, or other padding between and around them. If they can move quite freely in the box, they are likely to be cracked or otherwise damaged.

If cylinders are handled roughly at an early age, very small cracks are often formed in them. Even though these cracks may not be seen, they affect the strength greatly. Cardboard molds should not be removed from test cylinders for determining the quality of concrete before they are shipped to the Laboratory.

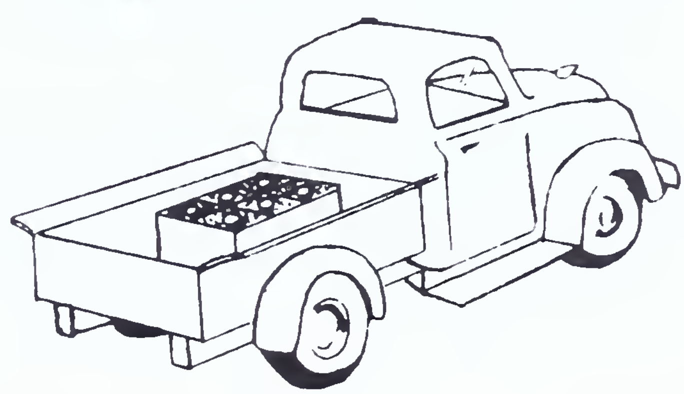
MAKING CONCRETE COMPRESSION TEST CYLINDERS



Use a Rounded-Nose Rod



Cure and Handle Cylinders With Care



For shipment to the Laboratory, test cylinders should be carefully packed in a stout wooden box. Burlap or paper padding should be wedged between the cylinders and the box to keep them from rattling around. Form 447 must be sent with the cylinders to identify them. This Form must show the class of concrete; slump; air content; route; date made; structure or part of structure represented; and any other information that should appear on the test report. Cylinders for 28-day tests should be shipped to the Laboratory, express collect, not more than 14 days after they are cast.

Weight Per Cubic Foot of Plastic Concrete

103. The unit weight, or weight per cubic foot, of freshly mixed concrete is usually found to check the yield, that is, the volume of the space in the forms that should be filled by one batch of concrete. The weight per cubic foot may also be used to find the actual cement factor, in bags per cubic yard, to check the air content, or to control the quality of the concrete.

In order that a quality-control test may be effective, the test result must be obtained quickly. Corrective action can then be taken before a large amount of defective material is placed in the structure. Cylinder and beam tests are not good quality-control tests for concrete, because it takes too long to get the results. The slump test is quick, but it is not a sure indicator of quality. The test for weight per cubic foot is quick, and the result is useful because anything that lowers the quality of the concrete shows up as a reduction in weight. The presence of an extra 1 percent of entrained air in the concrete reduces the weight per cubic foot by about 1.5 pounds. An increase of 1/10 gallon of water per bag of cement reduces the weight per cubic foot by about 0.4 pound. A lack of 0.2 bag of cement per cubic yard reduces the weight per cubic foot by about 0.1 pound. The quality and gradation of the aggregates also affect the unit weight.

In general, a unit weight of concrete much below the design value at the time it is being placed is an early warning of a reduction in the strength and durability of the hardened concrete. By making an additional test for entrained air with an air meter, any large reduction in unit weight caused by a high air content can be accounted for. Other probable causes of reduced unit weight can then be considered, if necessary.

Equipment for Test for Unit Weight

104. To determine the unit weight of freshly mixed concrete, the following equipment is needed: a cylindrical measure that will hold at least 1/2 cubic foot of concrete; a balance or scale that has a capacity of 100 pounds and is sensitive to the nearest 0.1 pound; a scoop and tamping rod like those used in the slump test, and a mallet or a piece of 2 x 4.

For concrete with aggregate particles not more than 2 inches in diameter the standard measure is a cylinder 10 inches in diameter and 11 inches high, which will hold 1/2 cubic foot. In some cases the concrete-holding part of an air meter can be used. The measure must be accurately calibrated. For this purpose, it is best to use a glass coverplate large enough to cover the top opening completely.

As the first step in the calibration process, the clean, empty measure with the coverplate on it is weighed as accurately as possible. This weight must be accurate to the nearest 0.1 pound. The measure is then filled completely with water at 62 degrees F., and the coverplate is fitted to the top. There should be no air bubbles under the coverplate. After the outside of the measure is dried, the total weight of the measure, coverplate, and water is found accurately. From this total weight, the weight of the empty measure and the plate is subtracted. The remainder is the weight of the water in the measure, in pounds. The volume of the measure, in cubic feet, is found by dividing the weight of water in the measure by 62.4, which is the weight of a cubic foot of water at 62 degrees F.

For example, if the weight of the measure and the coverplate was 16.15 pounds, and the weight of the measure filled with water at 62 degrees F and the coverplate was 47.45 pounds, the volume of the measure is found as follows:

Total weight	=	47.45 pounds		
Weight without water	=	16.15 pounds		
Weight of water	=	31.30 pounds		
Volume of measure	=	31.30/62.4	=	0.502 cubic foot

Filling Measure with Concrete

105. Instructions for collecting a composite sample of concrete to be used in the test for unit weight are given in Section 79 of this Manual. The measure should be filled with concrete from the well-mixed sample in three layers. The method of filling the measure is similar to that described for filling the slump cone or a mold for test cylinder. An outline follows:

Concrete for the first layer is poured into the clean, dry measure from the scoop in various directions, it is tamped 25 times with the rod in different locations (the usual care being taken to let the point of the rod reach the bottom of the measure without striking it hard), and the outside of the measure is tapped lightly about 15 times with the mallet. Tapping is continued until no large air bubbles appear on the surface of the layer. The operations just described for the first layer are repeated for the second layer. The tamping rod should not go more than 1 inch below the surface of the first layer. The measure should be filled to overflowing when the top layer of concrete is put into it. After the concrete has been rodded and the measure tapped, the surface should be struck off with a short straightedge, such as a straight piece of board. First the straightedge should be moved toward the edge. However, in the final step of the striking-off process, the straightedge should be worked from each part of the edge of the measure toward the center so that the concrete is a little higher at the center than at the edge and the measure is slightly overfilled.

The glass coverplate is now placed on the concrete and is forced down with a turning motion until it is in firm contact with the top of the measure all around the edge. If the plate will not go all the way down, it must be taken off and a little concrete removed. The plate should then be cleaned and replaced as before. There should be no air bubbles under the plate. If bubbles are seen, the plate must be removed and a small amount of mortar from the sample

of concrete must be added. When the plate is in firm and even contact with the entire top of the measure, and there are no air bubbles, any concrete on the outside of the measure or the outside of the plate should be wiped off. The concrete-filled measure with the coverplate on it is then weighed accurately, to at least the nearest 0.1 pound.

Computing Weight per Cubic Foot

106. The weight of the clean, empty measure and the glass coverplate and the volume of the measure will be known before the test for the unit weight of the concrete is begun. The weight of concrete in the measure is found by subtracting the known weight of the measure and coverplate from the total weight obtained in the test. The weight per cubic foot of the concrete with the entrained air is then computed by dividing the weight of the concrete by the volume of the measure.

Example 1. The weight of the empty measure and the coverplate is 16.15 pounds, and the volume of the measure is 0.502 cubic foot. If the total weight of the measure filled with concrete and the coverplate is found to be 89.77 pounds, what is the weight per cubic foot of the concrete?

The calculations may be made in this way:

Total weight	=	89.77 pounds
Weight without concrete	=	16.15 pounds
Weight of concrete		73.62 pounds

Unit weight = 73.62/0.502 = 146.65 pounds per cubic foot.

The weight per cubic foot of concrete without entrained air may be found as in the following example:

Example 2. The percent entrained air in the concrete in Example 1, as found by a meter test, is 4.8 percent. What would be the weight per cubic foot of air-free concrete?

Since the solid material in the concrete makes up 100 - 4.8 = 95.2 percent of the weight, the unit weight of air-free concrete would be 146.65/0.952 = 154.04 pounds per cubic foot.

Computing Yield Per Batch

107. The information obtained in the test for the unit weight of concrete can be used also for computing the actual yield per batch and the percentage of the theoretical yield. The total weight of materials in a batch of concrete is the sum of the known weights of fine aggregate, coarse aggregate, mixing water, and cement. The weight of cement per batch can be found by multiplying the number of bags used in a batch by 94, which is the net weight of a bag. The actual volume of a batch, in cubic feet, is found by dividing the total weight of a batch by the weight of a cubic foot of the concrete. A typical example follows:

Weight of damp fine aggregate in batch	=	1294	pounds
Weight of damp coarse aggregate in batch	=	1888	pounds
Weight of water added at mixer	=	180	pounds
Weight of cement in batch	=	587.5	pounds
Total weight of batch	=	3949.5	pounds

Unit weight of concrete = 146.65 pounds per cubic foot

Volume of concrete in batch = 3949.5/146.65 = 26.93 cubic feet

The theoretical yield of a batch of concrete is shown on next to the last line on Form 4220, Batcher-Mixer Slip. The percent theoretical yield can be found by dividing the actual yield per batch by the theoretical yield, and multiplying the result by 100.

Computing Cement Factor and Air Content

108. The actual cement factor, or the number of bags of cement per cubic yard of concrete produced, is computed by multiplying the number of bags of cement actually used in a batch by 27 and dividing the result by the actual yield per batch, in cubic feet. Thus, the actual cement factor for the concrete in the example given in the preceding Section is

$$\frac{6.25 \times 27}{26.93} = 6.27 \text{ bags per cubic yard}$$

The percent of entrained air in a cubic foot of concrete can be computed in the following way: The weight per cubic foot of the concrete, as found by the test for unit weight, is subtracted from the weight per cubic foot of air-free concrete, which is shown at the bottom of Form 4220, Batcher-Mixer Slip, and also on Form 4221, Mix Computation. The percent entrained air can then be computed by dividing the difference in weight by the weight of a cubic foot of air-free concrete, and multiplying the result by 100. For example, if the unit weight of the air-free concrete, in Example 1 in Section 106, is 154.04 pounds per cubic foot, the difference in weight is 154.04 - 146.65 = 7.39 pounds, and the percent entrained air is (7.39/154.04) x 100 = 4.8 percent.

General Features of Field Tests for Density

109. The purpose of making a density test in the field on material already in place in the construction is to find out how well embankment material, subbase material, or (in some cases) base material has been compacted by rollers or other equipment. The density of a construction material is the weight, in pounds, of the dry material occupying a cubic foot of space. The field test for density is made by digging a small hole in the compacted material, measuring the volume of the hole with calibrated sand* and determining the dry weight of the removed material. To find the density, in pounds per cubic foot, the dry weight of the material, in pounds, is divided by the volume of the hole, in cubic feet. This in-place density, or field density, is compared with the density of the same material compacted in a mold in the Laboratory, to find out if the material has been adequately compacted.

A change of about 1 pound per cubic foot in the in-place density produces a change of about 1 in the percent of laboratory compaction, which is found by dividing the in-place density by the laboratory density and multiplying the result by 100. Unless the error in measuring the in-place density is less than 1 pound per cubic foot, the computed percent of laboratory compaction cannot be considered accurate to the nearest whole number.

To obtain the most accurate results, the largest hole that can be measured with the test equipment should be dug. If one cubic foot of material could be removed from the test hole, and the volume of the hole could be measured, a total error of not more than 1 pound per cubic foot in the computed in-place density would make the percent of laboratory density accurate to the nearest whole number. However, the volume of the test hole is always much less than 1 cubic foot. If the hole is 4 inches in diameter and 4 inches deep, its volume is only 0.029 cubic foot. In order that the percent of laboratory compaction may be accurate to the nearest whole number in such a case, the total error in the computed in-place density cannot be more than .03 pounds, which is a little more than 13 grams. If the test hole is 6 inches in diameter and 5 inches deep, its volume is about 0.055 cubic foot. To permit the percent of laboratory compaction to be accurate to the nearest whole number, the total error in the in-place density must be less than about 1/18 pound, or a little less than 1 ounce.

The weight of a 3/4 inch particle of gravel is about 1/18 pound. Under average conditions, the loss of one such particle while the gravel is being removed from the test hole would change the computed percent of laboratory density by 1, say from 95 to 94 percent. Loss of material is not the only possible source of error. The surface of the material where the hole was dug may not have been perfectly flat; or the side of the hole may have been too rough to let the sand fill all the crevices; or vibration may have packed the sand in the hole more tightly than usual; or the weight per cubic foot of the sand used may not be correct because of errors in calibration or changes in moisture content. Other sources of error are lack of accuracy in weighing the material removed from the hole and incorrect moisture content.

Because of the many chances for error, a field test for density must be made with great care. Tests made under laboratory conditions on smooth holes 4-1/2 inches in diameter and about 5 inches deep showed that in 90 percent of the cases the volumes of the holes measured by using a glass jar and a 4-3/4 inch cone fell between 98 and 100 percent of the true volumes of the holes. Carelessness in any part of the test procedure will lead to false results, and possibly to acceptance of construction of poor quality.

Equipment for Field Test for Density

110. The volume of a test hole is measured best by using a device called a sand cone. The type of cone usually used is made up of three parts. The main part is a rotating valve with an opening 1/2 inch in diameter. A large funnel is attached to one end of the valve, and a standard "G" mason jar cap is attached to the other end by means of a small funnel. The small funnel and jar cap form what is known as a "pycnometer top". The valve should have stops

for the fully-opened and fully-closed positions. It must turn freely, since a sticking or rusty valve can cause an error of as much as 10 percent in the computed density. The funnel should be at least 6-1/2 inches in diameter at the large end. A rubber ring or gasket should be inserted between the mason jar cap and the glass jar on which it is placed. The volume of the glass jar should be at least three times the volume of the cone used with it. For any test-hole volumes less than 0.1 cubic foot, a 1-gallon glass jar may be used.

A base tray about 12 inches square, with a central hole slightly smaller than the bottom of the sand cone, is used as a guide in digging a test hole. It also helps to prevent the loss of material removed from the hole. After the hole has been dug, the tray is removed and the sand cone is placed over the hole on the prepared surface. Greater accuracy in measuring the volume of a test hole can be obtained by making a test on the prepared surface at the proposed location of the test hole before that hole is dug. The volume found in this test is used in correcting for any lack of evenness of the surface where the test hole is to be dug.

For digging a test hole in compacted material it is usually best to use a hammer and a long-handled chisel. Loosened material may be removed most easily with a large long-handled spoon made in one piece. The bowl of the spoon may be bent at an angle to the handle to make it easier to scoop the material from the bottom of the hole.

The sand used for measuring the volume of a test hole must be clean, dry, and free flowing. All of it should pass a No. 8 sieve, and not more than 5 percent should pass a No. 200 sieve; and it should be uniformly graded*.

Weighing equipment should consist of a large balance or scale which has a capacity of at least 25 pounds and is accurate to the nearest ounce; and a small balance for moisture tests which has a capacity of 500 grams and is accurate to the nearest 0.1 gram.

It is necessary to have heating equipment which is capable of drying rapidly samples of the size required for accurate moisture tests. A pan or dish on a stove may be used. A speedy moisture tester may be used, if available, but it must first be calibrated by comparing its readings with the results of standard moisture tests.

The following equipment is also needed: pans, dishes, or a 10-inch frying pan for drying moisture samples; buckets with lids; seamless tin cans with covers; canvas sacks or other containers for the density sample; one No. 4 sieve; a slide rule; and several copies of Form 478 on which to record measured qualtities and computed results.

Location of Test Hole

111. A density test must not be made when construction equipment is working within 30 feet of the test hole. Vibration by equipment will increase the amount of sand flowing into the test hole so that the result of the test may be in error by as much as 10 percent. The amount of compaction shown by the test will then be much lower than the compaction actually achieved. This source of error should be pointed out to the Contractor when it is necessary to get his cooperation in eliminating vibration.

The Inspector should have the Contractor place a course of the material to be tested over a definite area, compact this material, and then remove his equipment to another area. When a large number of tests are to be made on an area, the points at which tests are to be made should be fixed by a random sampling pattern or located by random methods. The District Soils Engineer will assist in setting up the random pattern.

When only one or two check tests can be made, the location or locations should be biased; that is, a test should be made at a point at which the density will probably be lowest. Such a point is usually in one of the following places; near the edge of an embankment; near, and on line with, a grade stake; between the paths of construction equipment; or in an area where compaction equipment is turned around.

The Contractor must compact all the material uniformly to the density required by the Specifications. If the density is satisfactory at the places that usually get the least compaction, it is probable that the rest of the area is fully compacted and has no weak places.

Forming Test Hole

112. Before a hole for the density test is dug, all loose material must be removed from the surface. If the material has been compacted only by sheepsfoot rollers, it may be necessary to remove a layer several inches deep. The compacted material should be trimmed to provide a firm level surface for the base tray. If the surface is rough, a trial test must first be made on the surface at the test hole, in order to get accurate results.

The minimum volume of a test hole depends on the size of the largest particles in the compacted material. For satisfactory accuracy the hole must have at least the volume and dimensions shown in Table IX.

TABLE IX - Required Size of Test Hole

Largest Particle Size	Least Volume of Test Hole, in Cubic Feet	Least Dimensions of Test Hole, in Inches Diameter	Depth
No. 4 sieve	0.025	4	3-1/2
1/2 in.	0.050	4	7
3/4 in.	0.063	5	5-1/2
		6	4
1 in.	0.075	6	4-3/4
2 in.	0.100	6	6-1/4

To reduce the probable chance for error, the depth of the test hole should be at least 6 inches whenever the compacted lift is thick enough.

A test hole should be formed in the following way: First, a small hole should be dug to the full depth. Then the sides should be trimmed without disturbing material that will not be removed. Care must be taken to prevent the loss of any material that is removed, including particles that stick to the tools.

All of the removed material should be placed as quickly as possible in a covered container, in order that no moisture will evaporate.

If possible, the material removed from the hole should be weighed immediately, and the weight recorded on Form 478. The material should then be mixed, and a sample for a moisture test should be taken and placed in a tightly sealed container. If the material cannot be weighed at the test location, all material removed from the hole should be placed in a tightly sealed container for shipment to the scale.

Finding Volume of Test Hole

113. The usual procedure for filling the test hole with sand is as follows: The glass jar is filled with calibrated sand,* the jar is attached to the cap on the sand cone, and the cone is set in position over the hole. It may be necessary to seal around the edge of the cone with soft clay after it is placed over the hole to prevent the escape of sand. The valve in the cone must be opened fully. A partly opened valve can result in a 5-percent error. Also, the sand cone must not be rocked or jarred while the sand is running into the hole. Vibration of the cone by construction equipment can result in a 10-percent error. When no more sand runs from the glass jar, the valve is closed fully without rocking or jarring the cone. The sand-cone assembly is then taken away from the hole and the cone is cleaned. Some of the test sand may be saved for reuse by scooping it out of the hole, but great care must be taken not to include any soil or gravel particles.

The volume of the test hole is found by filling in the proper spaces on Form 478. The procedure is shown here. Each item is numbered and described as it is given on Form 478.

First, the weights for Items 1 and 2 are found and recorded, and the weight for Item 3 is computed as follows:

1. Wt. of wet soil (+ aggregate, if any) from the hole + weight of container = ________ lb.
2. Wt. of container = ________ lb.
3. Wt. of wet soil (+ aggregate, if any) from the hole (#1 - #2) = ________ lb.

The soil from the hole is then put on a No. 4 sieve, and the weight of any aggregate retained on the sieve is recorded for Item 20. Thus:

20. Wt. of aggregate retained on No. 4 sieve = ________ lb.

Now, the soil is dried, the dry material is weighed, and the weight of moisture in the soil is computed by subtracting the weight of the dry soil from the weight of the wet soil. Then, the percent moisture in the soil, based on the heat-dried material, is found by dividing the weight of moisture by the weight of dry soil and multiplying the result by 100. This percent is

the value for Item 4 on Form 478, and the percents for Item 5 and either Item 5a or Item 5b can be put in. Thus:

4.	Percent of moisture of heat-dried soil	=	%
5.	Optimum moisture (from Laboratory report)	=	%
5a.	Amount above optimum moisture (#4 - #5)	=	%
5b.	Amount below optimum moisture (#5 - #4)	=	%

The weight for Item 6 on Form 478 is usually determined by the calibration procedure (see Section 115 of this Manual) and is then known before the test is made. It is good practice to use some convenient weight, such as 15 pounds, for this item in all tests, to lessen the chance of an error in recording the weight. The amount of sand put in the jar must then be adjusted to get the proper weight. The weight for Item 7 and the volume for Item 9 are always determined in the calibration procedure. If the weight for Item 6 is determined by the calibration procedure, the weight for Items 8 and 10 will also be known before the test is made.

The weight for Item 11 is found in the test by weighing the sand-cone assembly and the sand remaining in the jar after the test hole has been filled. The weight for Item 12 can then be computed. The weight for Item 14, which is constant for a particular sand cone, is determined in the calibration procedure. The weight for Item 13 is then entered on Form 478, and the volume of the hole for Item 15 is computed. Four decimal places must be used in this volume. Items 6, 10, 11, 12, 13, and 15 follow:

6.	Wt. of air-dry sand + wt. of density-cone apparatus	=	lb.
10.	Wt. of air-dry sand per cubic foot (#8 ÷ #9)	=	lb.
11.	Wt. of air-dry sand remaining in density-cone apparatus and wt. of apparatus	=	lb.
12.	Wt. of air-dry sand in hole and upper cone (#6 - #11)	=	lb.
13.	Wt. of air-dry sand in hole (#12 - #14)	=	lb.
15.	Volume of the hole (#13 ÷ #10)	=	cu.ft.

Finding Percent of Laboratory Compaction

114. When the material removed from the test hole contains no aggregate retained on the No. 4 sieve, the computed volume of the hole should be used to find the weight of dry material in 1 cubic foot of the soil, for comparison with the dry weight per cubic foot of the same soil as determined in the Laboratory. Items 15, 17 and 18 are then used. Also, the percent of Laboratory compaction obtained can be computed as indicated for Item 19. Items 16, 17, 18 and 19 follow:

16.	Wt. per cubic foot of wet soil in fill (#3 ÷ #15)	=	lb.
17.	Wt. of dry soil in 1 cubic foot of fill (100 x #16 ÷ (100 + #4)	=	lb.
18.	Max. dry wt. per cubic foot (from Laboratory report)*	=	lbs.
19.	Compaction obtained (#17 ÷ #18) x 100	=	%

*The Laboratory report number on the field proctor test number from which the maximum Dry Density was obtained should be shown on Line 18 or 26.

When the material removed from the hole contains aggregate retained on the No. 4 sieve, Items 20 to 27 are used instead of Items 16 to 19.

Average Specific gravities (av.sp.gr. in Item 21) for various types of aggregate are shown on Form 478. Good judgment must be used in selecting the specific gravity for Item 21, because the selection may determine whether the compaction is considered satisfactory or not. In order that the correct average specific gravity may be selected, the aggregate retained on the No. 4 sieve must be correctly identified. If the Inspector cannot decide without any doubt, the Soils Engineer should be consulted. It may be necessary to obtain a sample of the aggregate so that the specific gravity of the plus 4 material may be determined at the District or Department Laboratory. Items 20 to 27 follow:

20.	Wt. of wet aggregate retained on No. 4 sieve and removed from the material taken from the hole	=	________ lb.
21.	Volume of aggregate retained on No. 4 sieve (#20 ÷ (av.sp.gr. x 62.4)	=	________ cu.ft.
22.	Wt. of wet soil passing No. 4 sieve (#3 - #20)	=	________ lb.
23.	Volume of wet soil passing No. 4 sieve (#15 - #21)	=	________ cu.ft.
24.	Wt. of wet soil in 1 cubic foot of fill (#22 ÷ #23)	=	________ lb.
25.	Wt. of dry soil in 1 cubic foot of fill (100 x #24) ÷ (100 + #4)	=	________ lb.
26.	Max, dry wt. per cu. ft. (from Laboratory report)*	=	________ lb.
27.	Compaction obtained with plus No. 4 aggregate removed (#25 ÷ #26) x 100	=	________ %

Calibration Procedure

115. The results of calibration procedure are recorded on Form 478 by using Items 6, 7, 8, 9, 10, and 14. The sand placed in the glass jar for measuring the volume of the test hole may be an air-dry sand that meets the requirements in Section 110 of this Manual. Since sands have different specific gravities and gradations and behave differently during settlement, it is necessary to calibrate frequently each sand used in making the density test.

The weight for Item 7 on Form 478 is obtained by cleaning and weighing the sand-cone assembly. Thus:

7. Wt. of density-cone apparatus = ________ lb.

The procedure for finding the volume for Item 9 is as follows: The apparatus is set upright with the funnel and jar top assembly, (called a pycnometer top), and the sand cone attached to the glass jar and the flow control valve opened.

*The Laboratory report number on the field proctor test number from which the maximum Dry Density was obtained should be shown on Line 18 or 26.

The apparatus should be filled with water until some appears in the upper cone above the control valve. This valve should then be closed and any water in the upper cone should be removed. After the inside of the upper cone and the outside of the apparatus have been dried, the apparatus with water in it, is weighed. The volume of the water is then found as follows:

Wt. of apparatus + contained water = ________ lb.
Wt. of apparatus = ________ lb.
Wt. of contained water = ________ lb.

Since 1 cubic foot of water weighs 62.4 pounds, the volume of the jar and the pycnometer top, for Item 9 is found by dividing the weight of water in the apparatus by 62.4. Thus:

9 Volume of density-cone jar and pycnometer top = ________ cu.ft.

The procedure for finding the weight for Item 8 on Form 478 follows: The apparatus is emptied and dried thoroughly. Then the operations described for finding the weight of water in the apparatus are repeated using the air-dry sand to be calibrated instead of water. While the apparatus is being filled with sand, the upper cone should be kept about half full of sand, in order to get uniform flow of the sand into the glass jar. After the valve is closed, the sand remaining in the upper cone should be removed. The apparatus with the sand in it is weighed, and this weight is recorded as Item 6. The weight of air-dry sand in the apparatus is then found as follows:

6. Wt. of air-dry sand + wt. of density-cone apparatus = ________ lb.
7. Wt. of density-cone apparatus = ________ lb.
8. Wt. of air-dry sand in density-cone apparatus (#6 - #7) = ________ lb.

The density of the air-dry sand in the apparatus, all of which passed through the hole in the valve of the sand cone, is computed by dividing the weight for Item 8 by the volume for Item 9. This density is recorded as Item 10. Thus:

10. Wt. of air-dry sand per cubic foot (#8 ÷ #9) = ________ lb.

The procedure for determining Item 14, which is the constant weight of air-dry sand contained in the upper cone of the apparatus when the apparatus is inverted, is as follows: After the apparatus is filled with sand, it is turned upside down. With the base of the cone resting on a smooth, flat surface, the valve is opened and the air-dry sand is allowed to fill the cone. The valve is then closed and the apparatus with the sand in it is weighed. The weight found by subtracting the weight for Item 7 from the total weight with the sand is recorded as Item 15. Thus:

14. Wt. of air-dry sand in upper cone = ________ lb.

<u>Method of Calibrating Sand</u>

116. To get accurate results from a density test, the test equipment, the test method, and the sand used must be calibrated under conditions as nearly as possible the same as those that will exist at the places on the job where the test will be made.

The sand to be used can be calibrated in the following way: First, freshly mixed concrete is cast in the form of a block about 12 inches square and 8 inches deep. One part of cement to four parts of aggregate, by rough volume, will make a good mix. The concrete should have just enough water in it to permit it to be packed solidly but should have zero slump. Before the concrete hardens, a hole having the same size and shape as the usual test hole is dug in the concrete. The aggregate used should be of such size and gradation that the side of the hole will have nearly the same roughness as will the side of a test hole dug in the field.

After the concrete has set for about 3 hours, the hole should be filled with water to cure the concrete and make it waterproof. The next day, a wet piece of paper should be laid smoothly on a piece of glass the size of the top of the concrete block. Also, a stiff paste of cement and water should be prepared and spread with a trowel over the surface of the concrete around the hole. The paper-covered glass plate should then be pressed firmly on the paste (with the paper in contact with the paste) until paste is forced out around the edges of the glass and the glass is nearly touching the block. The concrete and the glass should be covered with wet burlap for 3 days. The burlap and glass should then be removed, and the paper rubbed off.

The water is now dumped out of the hole, and the side of the empty hole is dried with a damp cloth. A measured amount of water is then poured into the hole so that it is just full. The fullness should be checked by placing the glass plate on top of the block. When the hole is filled correctly, there will be no air bubbles under the plate, and no water will be forced out by the plate. The true volume of the hole is found from the volume or weight of water required to fill it.

To calibrate the sand, the water is dumped out of the hole, the side of the hole is wiped with a damp cloth, the concrete is allowed to become completely air dry, and the hole is filled with the sand in the usual way as when making a test in the field. Divide the weight of sand needed to fill the hole by the volume of the hole to find the weight per cubic foot. (Item 10 Section 113).

Checking Results of Field Tests

117. The degree of compaction and the percentage of moisture determined by the field density and moisture tests must be compared with the requirements of the Specifications. The minimum requirements for field compaction are controlled by the maximum laboratory dry weight and the height of the embankment, in accordance with "Condition I" or "Condition II" as shown in the table "Embankment Soil Compaction Requirements."

If the soil does not contain enough moisture to permit the required density to be obtained, additional water will have to be mixed with the soil. If the soil contains more than the amount of moisture required to obtain the necessary compaction density, it should not be placed in the embankment, without written approval, until it has been allowed to dry so that its moisture content before compaction is not more than 2 percent above the optimum moisture content. Drying of wet soil may be speeded by disking or some other approved method.

The proposed height of the embankment and the minimum applicable compaction requirement must be recorded on each density-test report in the space provided.

Comparison of the compaction obtained with the required compaction will show when additional rolling is needed. If an embankment must be rerolled and retested, this fact should be noted on the density report.

When the percent of laboratory compaction indicated by the field test is very high (100 percent or more), the accuracy of the test should be checked in the following way: For any density of soil, the maximum amount of water theoretically possible in the soil when all the voids are filled with water may be taken from Table X. If the maximum content found from Table X is less than the moisture content recorded as Item 4 on Form 478, the test result is probably in error. When the field compaction is 110 percent or less, the moisture content for Item 4 must not be more than 2 percent above the theoretical maximum water content. When the field compaction is greater than 110 percent, no excess in moisture content is permitted.

TABLE X - Maximum Moisture Content of Soil

Unit Weight of Dry Soil, in Pounds Per Cubic Foot	Maximum Water Content, in Percent of Dry Weight
90	31.9
92	30.4
94	28.9
96	27.6
98	26.2
100	25.0
102	23.7
104	22.6
106	21.4
108	20.3
110	19.3
112	18.3
114	17.3
116	16.3
118	15.4
120	14.6
122	13.7
124	12.9
126	12.1
128	11.3
130	10.6

CHAPTER XII

GLOSSARY

ABSORPTION - The process of a solid taking up liquid by surface wetting and capillarity, as a sponge takes up water.

ABUTMENT - Supporting structure at the end of a bridge.

ACETYLENE TORCH - A nozzle having valves to control the flow of acetylene and oxygen gases and devices to combine them so that they may be burned to produce a very hot flame used for cutting or welding metal.

ACCURATE - A rifle is accurate when it will group all bullets around the bull's-eye of a target. Compare with PRECISION.

ADHESION - The force by which one substance clings to another of a different nature.

ADMIXTURE - Any material, other than portland cement, aggregates, and water, added to a concrete batch just before or during mixing.

AFFIDAVIT - A written statement made on oath before a notary public.

AGGREGATES - Sand, gravel, crushed stone, or crushed slag used to make up the solid volume of a bituminous paving mixture.

AGGREGATES (COARSE) - Coarse aggregates are those having certain specified gradations. Aggregates with most of the particles larger than 1/4 inch are usually called coarse aggregates.

AGGREGATES (FINE) - Most of the particles in fine aggregate for concrete are less than about 1/4 inch in size and all must be smaller than 3/8 inch.

AGGREGATE VOIDS - The space in a compacted bituminous mixture not filled with aggregate. Usually reported as a percentage of the bulk volume of the compacted material.

AGRICULTURAL LIME - Powdered limestone.

AIR-ENTRAINING AGENT - A substance used in concrete to increase the amount of entrained air in the mixture; entrained air is present in the form of very small bubbles.

AIR VOIDS - The space in a compacted bituminous mixture not filled with bitumen or aggregate. Usually reported as a percentage of the bulk volume of the compacted material.

ALIGNMENT - The ground plan of a highway as seen from above and as shown on a map or drawing. Also called horizontal alignment. Sometimes spelled alinement.

ALLIGATOR CRACKING; CHICKEN WIRE CRACKING - Interlaced cracking of a bituminous wearing course into small, irregular, blocks. Caused by lack of base support.

AMPLITUDE - The distance a particle is moved by a vibrator.

ANCHOR BARS - Small steel bars or straps, usually with hooked ends, welded to expansion joints used in structures. After the concrete next to the joint has hardened, the anchor bars hold the joint firmly in place.

ANCHOR BOLTS - Bolts partly embedded in concrete to support and hold down a structural member.

AREA - The total surface of anything.

ARCH - A structure with a curved under surface that supports a highway over an opening. Structurally, an arch carries vertical loads by the resistance of the abutments to horizontal thrusts.

ASHLAR RUBBLE MASONRY - Masonry composed of squared stones with finished faces laid in horizontal courses and held together by mortar.

ASPHALT - A black, sticky, bituminous material, usually produced by distilling crude petroleum oil.

ASPHALT CEMENT - Refined asphalt ready for use for paving purposes which meets Specification requirements (Bull. 25).

ASPHALTIC CONCRETE - A uniform mixture of graded coarse aggregate, graded fine aggregate, mineral filler, and asphalt cement.

ASSEMBLY FOR TRANSVERSE EXPANSION JOINT - Framework of light steel rods that holds the parts of a joint, such as dowels, steel plates, and expansion-joint filler, in their correct relative positions.

AUTOMATIC CONTROL - Operation of a machine or paving plant by electronic or mechanical adjustment of the regulating devices.

AXIS - A straight line through the center of an object. The axis of a slump cone is a straight line passing through the centers of the circles formed by the top and the bottom of the cone.

BACKFILL - To refill a ditch or other excavation; or the material used for refilling.

BACKSLOPE - The portion of the earth grade or roadway in a cut section which is beyond a side ditch and rejoins the original ground.

BACK WALL - Top portion of an abutment, generally forming the rear, vertical portion of a notch which supports the end of the bridge superstructure (bridge seat). It also holds the end dam or expansion device in place.

BAFFLE - A steel plate at the discharge end of a concrete chute. Its purpose is to change the direction of flow of the concrete.

BAR CHAIR - A device that holds a reinforcing bar (or bars) the right distance above forms for concrete.

BASE; BASE COURSE - A layer or layers of specified or selected material of planned thickness placed and compacted on a subbase or a subgrade to support a surface course.

BASE METAL - The original steel in a part to be joined to another part by a weld. The weld consists of a mixture of the base metal and the material of the electrode.

BATCH - The combined weights of aggregates and cement which will produce a known volume of concrete.

BATTER - The inclination from the vertical of a pile or a face of a wall.

BEAM TESTS - Tests of small concrete beams molded on the job and later broken in a testing machine to find the strength of the concrete.

BEARING AREA - The part of the top surface of a mass of concrete (a pier, abutment, or footing) on which a part of a bridge is directly supported.

BEARING ROCKER - Movable support at one end of a bridge span which rocks on its base to provide for changes in span length.

BELTING - The final finishing of the surface of a concrete pavement. A burlap drag is used to distribute surface mortar evenly and to leave a gritty surface.

BENCH - A wide, nearly level step or shelf graded into a hillside between steep slopes.

BENCH MARK - A definite point of known elevation and location used for determining the elevations of other points.

BERM - (An artificial ridge of earth.) A narrow horizontal shelf in a slope.

BIAS - Favoring one kind of result.

BINDER - The bituminous material used to bind the aggregate particles together in a paving mixture.

BINDER COURSE - A plant mix of graded aggregate (generally open graded) and bituminous material which is placed between the base course and a bituminous surface course.

BINDER MIXTURE - A bituminous mixture, usually made with larger coarse aggregate, less fine aggregate, and less bituminous material than a wearing course, used for construction of a binder course.

BITUMEN - A cementing material that can be dissolved in a chemical called carbon disulfide or carbon tetrachloride.

BITUMINOUS CONCRETE - A designed combination of dense graded mineral aggregate, filler, and bituminous cement, mixed in a central plant and laid and compacted while hot.

BITUMINOUS MACADAM; PENETRATION MACADAM - Constructed as follows: 1) placing and compacting a layer of one-sized aggregate, usually about $1\frac{1}{2}$ inches in size, and then applying bituminous material to be absorbed into the layer by penetration; 2) adding one or more spreadings of finer aggregate to fill the voids, and spraying each spreading of finer aggregate with bituminous material.

BITUMINOUS MATERIAL - A material containing bitumen. The bituminous materials usually used for road construction are the various grades of asphalt and coal tar.

BITUMINOUS ROAD MIX - Mineral aggregate and bituminous material mixed on the road by the use of blade graders, drags, or special road mixing equipment.

BITUMINOUS SURFACE COURSE (TYPE JA-1) See sheet asphalt surfacing.

BITUMINOUS SURFACE TREATMENT - The application of bituminous material and aggregate to an existing road surface. Usually less than 1 inch thick.

BLEED - See bleeding.

BLEEDING - Flow of water from freshly placed concrete when no outside force is applied.

The flushing to the surface of excess bitumen in a bituminous pavement.

BLOWING - The surging of water and mud along the edges of concrete pavement caused by the downward movement of the slabs under heavy wheel loads.

BLOW-UP - The buckling or shattering of a concrete pavement at a transverse joint or crack, caused by the lengthwise expansion of the pavement.

BOLTS - Devices for fastening together two or more pieces of steel in a structure. A bolt has a preformed head at one end; the other end is threaded to receive a nut.

BOND - The adhesive force between steel bars or wires and hardened concrete. The steel is embedded in plastic concrete, and bond develops as the concrete hardens.

BORROW EXCAVATION - The excavation and disposal, as directed, of satisfactory material from borrow pits when specified in the Contract item. The borrow pits must be located entirely beyond the limits of the highway. Borrow excavation also covers the removal of top soil, as provided for by the Specifications.

BORROW PIT - An excavation from which material is taken to be placed in the construction.

BRIDGE - A structure with a span of at least 8 feet to carry a highway over a water-course or other opening or for allowing water to flow under the highway.

BRIDGE DECK - The part of a bridge floor that forms the roadway.

BRIDGE SEAT - The surface of a bridge abutment or pier on which the superstructure rests.

BRIDGING - When concrete extends across or through a joint so that the concrete must be broken to permit movement at the joint, the joint is said to be bridged. Bridging is most serious at an expansion joint, since movement at the joint will be prevented unless the concrete spalls or cracks.

BROOMING - Separation of the wood fibers at the tip or butt of a timber pile.

BULKHEAD - Usually a heavy timber placed across the pavement and between the forms as a stop for the placing of concrete. At a joint location the bulkhead is made of two pieces of timber each equal in height to about one-half the thickness of the pavement. The meeting faces of the timbers are notched in such a way that the dowels in the joint can extend through the bulkhead.

A partition made of timber, concrete, or steel plate, placed between stockpiles to prevent their intermixing.

A vertical form set at a construction joint or an expansion joint in a wall, beam, or slab.

BURNING - In brick manufacture bricks are "burned" by heating to a high temperature in a brick kiln.

BUTT - The larger (Usually the top) end of a pile.

CALCIUM CHLORIDE - A white salt, in the form of flakes or pellets, which can be dissolved in water and used during coald weather to cause concrete to gain strength more quickly. Also used for ice control on completed bridge decks and highways.

CALIBRATE - To compare with a standard, or to check the graduations of a gage or other measuring device.

CALIBRATED SAND - Sand of known density (weight per cubic foot) under the conditions of making a sand-cone density test.

CALKING - Using a tool to force the lip of the head of a loose rivet against the connected piece.

CAMBER - Extra height provided in forms for arches or beams to allow for settlement of the forms due to the weight of the fresh concrete.

CARBORUNDUM STONE - A disk or bar of an abrasive material (silicon carbide) used to remove fins and other projections from the surface of hardened concrete by rubbing.

CARRY-OVER - Material which fails to pass through the proper screen and is found in a bin which should contain only larger material.

CAST-IN-PLACE CONCRETE PILE - A pile formed by driving a thin steel shell fitted to a temporary pile called a mandrel, removing the mandrel, and filling the shell with concrete.

CC - Means cubic centimeter, a unit of volume in the metric system of measurement. For all practical field laboratory purposes, this unit of volume is the same as a milliliter (ml), which is a unit of capacity.

CEMENT - The substance used for binding particles of aggregate together to form a pavement structure.

Portland cement is a manufactured powder which, when first mixed with water, forms a plastic paste that coats the particles of aggregate in concrete; when the cement paste hardens, it binds the aggregate particles firmly together.

CEMENT PASTE - A mixture of portland cement and water.

CEMENT RUBBLE MASONRY - Masonry composed of well-shaped stones laid in nearly horizontal courses and held together by mortar.

CEMENT-SAND BED - A mixture of one volume of portland cement to five volumes of Type B fine aggregate. The mixture is laid to a depth of 3/4 inch on a prepared base and shaped with a template to a true surface on which brick is laid.

CENTERING - The formwork for an arch and its supporting framework.

CERTIFIED REPORT - A report from a laboratory setting forth test results vouched for by a responsible person.

CHAMFER - The inclined flat surface formed by removing a square edge or corner.

CHAMFER STRIP - A small V-shaped strip placed inside a corner of a form to shape a beveled edge on the concrete.

CHEMICAL TEST - A test made to find the makeup of a material.

CHUTE - An inclined trough for leading mixed concrete into forms.

CINCHED UP - Tightened by means of a cable or chain placed around an object such as a band used for joining corrugated metal pipe.

CLAIM - A formal request by the Contractor for additional money or time.

CLAY - A heavy soil made up of very fine particles. Clay is soft and sticky when wet, but forms very hard lumps when dry. The lumps remain hard for some time after being placed in water. Wet clay is easily formed into threads by rolling a small portion between the thumb and finger.

CLEAN - Free from foreign material. When used to describe sand or gravel, it means a lack of clay or other fine soil that would cause the particles to stick together.

COAL TAR - A bitumen made by distilling bituminous coal at high temperature.

COAL-TAR CEMENT - Refined coal tar ready for use for paving purposes and meeting Specification requirements (Bulletin 25).

COFFERDAM - A structure built around a foundation site to keep water out of the excavation.

COHESION - The property of a soil that makes the particles stick together (clay is a cohesive soil).

The property of a bituminous mixture that holds the mass together.

COLD JOINT - A joint in a concrete structure made by placing fresh concrete against older, hardened or partially hardened concrete.

A joint made by placing hot bituminous mixture against a bituminous mixture that has cooled.

COLLOIDS - Particles of soil so extremely small that they remain suspended in water for long periods of time.

COLUMN - A vertical member that supports one end of a beam.

COMPACTED - Made more dense. When a material is compacted, the particles are forced together more tightly so that a given weight of material takes up less space.

COMPONENT (MATERIAL) - One of the materials or parts which make up a complete mixture.

COMPOSITE SAMPLE - A sample made by putting small samples together.

COMPOUND - See CURING MATERIAL.

COMPRESSION; COMPRESSIVE STRESS - The stress produced in a member when the forces acting on it tend to push the parts together.

CONCRETE - A mixture of portland cement, water, sand, and gravel, crushed stone, or crushed slag, with or without some other material such as calcium chloride or an air-entraining agent.

CONCRETE BLOCKS - Hollowed or solid building units, usually 8 inches high and of various shapes, made of concrete in a block plant and shipped to the job.

CONSISTENCY - The degree of firmness of plastic concrete, as indicated by the ease with which the concrete can be placed in the forms or as measured by the slump test.

CONSTRUCTION JOINT - A joint formed in a concrete structure when placing of concrete must be stopped for a comparatively long time.

CONTACT AREA - The area (square inches) of a rubber tire touching the surface which supports it.

CONTACT PRESSURE - The wheel load, in pounds, divided by the square inches of contact area. Sometimes called ground pressure.

CONTOUR LINE - A line on a map or drawing, or an imaginary line on the ground, that connects points of equal elevation.

CONTRACTION JOINT - A joint which fixes the position of a crack but which does not permit expansion.

CONTRAST SEAL - A seal coat used to provide color or texture contrast to the surface next to it.

COPING - A course of concrete or stone placed on top of a wall to shed water.

COPPER FLASHING - Copper in the form of very thin sheets, used to weatherproof joints or edges of a structure.

CORES - Cylinders of concrete cut from the pavement with a hollow drill. The drill grinds away a ring of concrete all the way through the pavement so as to leave the core undamaged in the center of the drill. Cores are usually 6 inches in diameter and are used to check the thickness, and sometimes the strength, of the concrete.

CORRELATION - A close relationship between two properties.

CORRUGATED METAL PIPE - Flexible pipe formed of galvanized steel plates, riveted together, with ridges and furrows extending around the pipe to give it added strength.

COVERAGE - A single passage of a wheel over an area of pavement.

CRACK - A fissure or open seam that does not necessarily extend completely through the body of a material.

CRIBBING MEMBERS - Beams used to form a framework holding earth in place.

CROSS SECTION - In the field, elevations taken along a line at right angles to the centerline. On a drawing, a profile of the existing ground at right angles to the centerline. The drawing of an earthwork cross section also shows the shape of the finished excavation or embankment at the same point. A roadway cross section shows the thickness and width of the pavement courses.

CROWN - The height of the center of a roadway surface above its edges.

CRUDE OIL - Petroleum as found in nature, just as it comes from a well.

CRUSHER-RUN - The product of the crushing plant without being screened or separated into various sizes.

CULVERT - A structure that has an opening less than 8 feet wide, and that permits water to flow through an embankment (if the opening is wider, the structure is called a bridge).

CURING - Treating concrete by covering its surface with saturated burlap to prevent the rapid evaporation of the mixing water in the concrete.

CURING MATERIAL - A material, such as saturated burlap, a special kind of paper, or a compound that is sprayed on the concrete, which is used to prevent evaporation of water.

CUT - To lower the level of the surface of an existing grade.

The total amount of excavation in a section of roadway.

The vertical distance from the existing ground surface to the planned grade line at a given point.

CUT-BACK ASPHALT - An asphalt cement that is temporarily made liquid by the addition of a solvent such as naphtha, gasoline, or kerosene.

CUT-OFF SHOE - An attachment, fastened to the screed unit of a bituminous paver, used to reduce the width of lane.

DECK - The floor of a bridge.

DEFECT - A fault or flaw that causes a material or a construction to be outside Specification requirements.

DEFORMED BAR - A steel bar, which has projections on its surface, used for reinforcement in concrete (the bond between the concrete and the steel is increased by deforming the bars).

DELETERIOUS - Harmful.

DELIQUESCENT - Becoming liquid on exposure to air by picking up moisture.

DENSITY - The weight of one cubic foot of a material.

DENSITY TEST - A test made to find the weight of one cubic foot of a material.

DEPARTMENT - The Pennsylvania Department of Highways.

DEPARTMENT SEAL - The official seal of the Pennsylvania Department of Highways.

DETERGENT - A cleansing agent.

DIMENSION - A measurement, such as length, width, or height.

DISINTEGRATION - Breaking up into small pieces or particles for any reason.

DISPERSING AGENT; DEFLOCCULANT - A material having the ability to cause the separation of small clumps (floc) of finer materials when they are suspended in water.

DISTORTION - Any change of a pavement surface from its original shape.

DIVIDED HIGHWAY - A highway with separated roadways for traffic in opposite directions.

DOME - The raised opening through which a tank car is filled from the top.

DOWELS - Short steel bars embedded in two parts of a concrete structure to hold the parts in place.

DOWELS (LONGITUDINAL JOINTS) - Hook bolts (12 foot lane) or straight bars #5 x 4 feet long (24 foot lane) placed across longitudinal joints to tie the lanes together

DOWELS (TRANSVERSE JOINTS) - Steel bars 1 inch in diameter and 18-1/2 inches long that extend into the concrete on both sides of a transverse joint. Dowels transfer load from one slab to the other across the joint and hold the edges of two slabs at the same elevation.

DOWEL SHIELDS - See LONGITUDINAL KEYS.

DOWELED KEYWAY - The longitudinal tongue and groove joint formed between 12-foot lanes of pavement by the dowel shields and hook bolts.

DRAIN - A pipe, trench, or ditch provided for the purpose of leading water away from a structure.

DRAINAGE - The system of ditches, trenches filled with pervious material, or pipes designed to lead water away from the pavement. Surface drainage carries away the water resulting from rainfall or melting snow. Subdrains are used to cut off water flowing through the ground before it reaches the ground under the pavement. They are also used to remove water coming from the ground beneath the pavement or collecting in the subgrade or subbase.

DRAINAGE CASTINGS - Cast-iron items, such as manhole frames or inlets.

DRESSED SHEATHING - A sheathing that has been smoothed by planing.

DRIER - A large, revolving, metal cylinder with narrow shelves (flights) on the inside, set at a small slope. The combined aggregates, fed to the high end, are heated as they travel through the drier by a fire, usually produced by the burning of fuel oil or gas at the lower end.

DRIFT PIN - A cigar-shaped piece of steel used to line up rivet holes.

DRIVE (A RIVET) - To hammer a heated rivet so that it fills the holes in the members to be connected and a second head is formed on it.

DRIVEN TO REFUSAL - The condition of a pile which has been driven until it cannot go any further into the ground.

DROP HAMMER - A pile hammer, which is basically a heavy metal weight that is allowed to fall through the air and strike the top of a pile.

DUCTILITY - As applied to asphalt, the distance to which a small sample of standard form can be drawn at a standard rate and temperature before it breaks.

DUST - Rock flour. See FILLER.

ELEPHANT TRUNK - A large, flexible tube through which concrete can flow vertically into forms without becoming segregated.

EDGER - A small hand tool used to round the edges of concrete slabs before the concrete has hardened.

EFFLORESCENCE - A whitish deposit left on the surface of concrete when water carries salts to the surface and then evaporates.

ELECTRODE - Material used with base metal to form a weld.

EMBANKMENT - A raised mass of soil or rock used to carry a road over a low area.

A fill, the top of which is higher than the ground next to it.

EMBANKMENT FOUNDATION - The material below the original ground surface whose physical characteristics affect the support of the embankment.

END DAM - Device, at the expansion end of a bridge, that covers the space between the end of the deck slab and the back wall of the abutment.

EMULSION - An asphalt emulsion is a suspension of extremely small droplets of asphalt in water in the presence of an emulsifying agent, which is usually a type of soap.

ENTRAINED AIR - Air that is mixed into the concrete, usually in the amount of about 3 to 7 percent of the volume of the concrete. To get the air into the concrete an air-entraining agent must be ground with the cement or added at the mixer. The air forms very small bubbles in the concrete.

EROSION - Wear caused by the force of moving water, or in some cases by wind.

EXPANSION END - The end of a span that is free to move in a lengthwise direction.

EXPANSION JOINT - A narrow space left between two parts of a concrete structure and filled with a compressible material to allow for expansion and contraction of the concrete with changes in temperature and loading.

EXPANSION-JOINT MATERIAL - Material that can be easily squeezed into a smaller space and that is placed in a joint.

FABRICATED STRUCTURAL STEEL - Steel members made by fastening steel shapes, such as plates and angles, together by riveting or welding.

FABRICATING PLANT - A plant where steel members are riveted or welded together to form steel beams, trusses, or other parts of steel structures.

FACE - The end of a working excavation.

FALSEWORK - A framework of wood or steel used to support the forms for a concrete structure or part.

Any construction needed to provide temporary support for a steel member during erection of a bridge.

FAULTING - Difference of height of the concrete slabs on opposite sides of a joint or crack. Caused by slab movement.

FEATHER-EDGE - A thin tapered edge in a concrete part.

FILL - Embankment of earth or broken rock.

FILLER - In a bituminous paving mixture, the mineral filler is that part of the total aggregate which will pass a No. 200 sieve. A filler material is an aggregate of specified gradation added to the other aggregates to increase the quantity of filler in the mixture.

In a brick pavement, the filler is a mortar containing portland cement and Type C fine sand that will flow into, and fill, the spaces between paving brick.

FILLET WELD - A triangular weld joining two surfaces at right angles to one another.

FILTER MATERIAL - Clean granular material which is pervious to water but will not permit the entrance of soil particles.

FIN - A projection on a concrete surface caused by a leaky joint in the forms.

FINES - Clay or silt particles in soil.

FINISHER - Skilled and experienced workman who brings the surface of the concrete to its final condition. He corrects any high or low places in the surface of the concrete, and brings it to a true grade and cross section by the use of tools, such as straightedges. He also rounds the edges of the concrete slabs next to the forms, or at joints, by the use of an edger.

FINISH GRADE - The final grade required by the Specifications.

FLASHINGS - Sheets of thin metal or other material used to guide water away from joints.

FLEXIBLE BASE - A base with low resistance to bending so that it stays in contact with the underlying structure. This type of base distributes loads to the foundation by aggregate interlock and particle friction and cohesion. Examples are macadam (wet and dry bound), dense graded aggregate, and all bituminous types (black bases).

FLEXIBLE PAVEMENT - A pavement constructed by placing some type of bituminous paving material on a flexible base.

FLOAT - A straight piece of wood or metal, usually between 3 and 10 inches wide, used to smooth the surface of plastic concrete. Small hand-held tools are called paddle floats. A finishing machine that causes a large metal float to move across the pavement is called a longitudinal finisher.

FLUX OIL - A non-evaporating oil or liquid asphalt used to soften hard asphalt.

FLYASH - Very fine material produced when powdered coal is burned.

FOG SEAL - Mixing-grade emulsion, diluted with water, sprayed on a bituminous surface. Usually applied at the rate of about 0.05 gallon per square yard, measured before dilution. No cover aggregate is used.

FOOTING - The part of a structure that rests directly on the surface of the ground, or on an underlying layer, and distributes the load from the structure.

FOREIGN BORROW EXCAVATION - Excavation which is obtained from sources outside the limits of the project and which will not or cannot be measured in its original position.

FOREIGN MATERIAL - Any substance or material occurring in another material or mixture where it is not normally found. Coal is a foreign material when found in aggregates.

FORMS - Assemblies of wood or metal that hold concrete in place while it is hardening.

Rigid sections fastened together along the sides of a paving lane to support the constuction equipment and to hold the freshly placed concrete until it hardens. The sections are usually made of steel in 10-foot lengths, equal in height to the finished pavement and with bases at least 8 inches wide. When set in position, the forms determine the alignment, grade, and thickness of the concrete pavement.

FORM BED - The part of the surface of the subbase on which the bases of the form sections rest.

FORM TIES - Metal devices of various kinds that prevent the forms for a concrete member from being spread apart when the concrete is placed in them.

FOUNDATION - The part of a structure that rests on the ground and supports the weight of the structure.

FOUNDATION COLUMN - A vertical concrete member that rests on rock or other firm material below the surface of the ground, and is constructed by placing the concrete in a steel shell, which is gradually removed as the concrete hardens.

FREQUENCY - The number of times a particle is moved in one direction by a vibrator in one minute.

FRIABLE - A soil that can be easily broken and crushed by moderate finger pressure.

FROG - A tool used for tamping and compacting soil mixtures. It is powered by an engine which causes it to leap from the ground.

FROST BOIL - When the subgrade or some portion of a flexible pavement contains silt, ground water may freeze and form a body of ice which grows in a lens shape to raise the surface of the pavement and cause a frost heave. When the ice melts, support is lost, and the breaking up of the pavement over the point where the ice lens was located is called a frost boil.

FUEL OIL - A light oil, such as kerosene, used as diesel fuel and as a solvent for MC type asphalt cut-backs.

FULCRUM POINTS - Sharp edges of hardened steel that support the lever arms of a scale used for weighing materials.

FULL DEPTH OF PENETRATION - The distance a tool, such as a sampling thief, is pushed into the material being sampled.

GAP GRADED - A gradation lacking one or more fractional grain sizes.

GASOLINE - An inflammable liquid, produced from petroleum, used as a motor fuel and as a solvent for RC type asphalt cut-backs.

GEL - The binding substance produced when cement and water combine under proper conditions.

GOVERN - In the case of two or more different rules, directions, or results having to do with the same thing, the one said to govern is the one to be followed. If a note on a drawing differs from the requirements of the Specifications, the note governs and is to be followed.

GRADATION - A general term used to describe the composition by size of the aggregate in a mixture. Gradation is usually expressed as the proportion (percent) of the aggregate that will pass each of several sieves of different sizes.

GRADE - The elevation of the surface of the pavement slab, subbase, or subgrade.

The profile of the center of the roadway, or its rate of rise and fall. On a 6 percent grade there will be a rise or fall of 6 feet between two points 100 feet apart.

To establish a profile by cuts anf fills of earthwork.

GRADE LINE - A line on a drawing showing the elevation of the completed pavement along the length of a project. Also called the profile.

GRADING - All construction operations between site clearing and paving. Grading includes all excavating, hauling, spreading, and compacting operations.

GRADING SECTION - A length of the construction, shown on the Drawings, within which the volume of excavated material has been computed in its original and final positions.

GRADE STAKES - Stakes driven so that their tops show the level of the final grade line or finish grade (usually of the subgrade or subbase). Sometimes called "blue tops."

GRANULAR MATERIAL - A material that can be formed easily into an 8-inch loose layer and that does not contain more than 35 percent of fine soil particles which will pass a No. 200 sieve.

GRAPHITE LUBRICANT - A compound used on dowels and made of flake graphite, oil, and a thinner that will evaporate. Graphite, which is a form of carbon, is slippery even when dry and permits the dowel to slide easily in the hardened concrete.

GRAPHITE PASTE - A mixture of finely powdered graphite and a liquid which evaporates quickly.

GRAVEL - Rounded pieces of rock from about 1/8 inch to 2-1/2 inches in diameter.

"GREEN" CONCRETE - Concrete which has set but has not hardened fully.

GREEN LUMBER - Wood which still contains most of the water that was in it when the tree was cut down.

GROUND FINISH - A smooth finish on a concrete surface obtained by removing a thin layer of concrete with an abrasive tool or a suitable grinding machine.

GROUT - A relatively thin (liquid) mixture of cement, fine sand, and water, or of cement and water only.

GUARD FENCE - A fence built along the edge of a highway to help prevent cars from running off the road.

GUARD STAKES - Long wooden stakes driven around a layout stake to prevent it from being disturbed during construction.

GUNITE - A type of portland cement mortar "shot" into place by compressed air. The materials are mixed while being forced through a nozzle. Sometimes called shotcrete.

GUNITING - Application of a coating of mortar to a surface with a "cement gun;" the mortar is commonly known as "gunite."

HAIR CHECKING - Small cracks, having a regular pattern, which extend partly through the depth of a pavement course.

HAIR CRACKS - Very small cracks that form in the surface of freshly placed concrete. They are usually caused by rapid evaporation of water from the concrete surface because of high temperatures or wind.

HAUNCHES - The lower quarters of a circular pipe laid in a trench.

HEAD - The vertical distance from some reference level to the upper surface of a body of water.

HEADER - A piece laid in a wall crosswise (at right angles to the vertical face of the wall).

HEADER CURB - A cement concrete curb constructed along each edge of the pavement as part of the concrete base. The width is 9 inches and the height above the base is 1/4 inch less than the thickness of the bituminous surfacing placed on the base.

HIGH-EARLY-STRENGTH CEMENT - High-early-strength cement differs from regular cement in chemical composition, is usually ground finer, and is more expensive. Concrete made with high-early-strength cement reaches a certain strength earlier than that made with regular cement.

HIGHWAY; ROAD - A general term describing a public way for purposes of travel. It includes the entire area within the right-of-way.

HONEYCOMB - An area in concrete where there is a nest of particles of coarse aggregate and a lack of mortar to fill the spaces between them.

HOOK-BOLT DOWELS - Short steel bars with hooked ends joined by a threaded connection. Used to fasten a concrete slab to another later constructed next to it.

HORIZONTAL ALIGNMENT - See ALIGNMENT.

HOT BINS - Bins used for the temporary storage of dried and heated aggregates that have been separated into sizes by the screens. Usually placed above or near the pugmill used for producing a hot-mix bituminous mixture.

HOT ELEVATOR - An enclosed bucket elevator that raises the heated aggregates from the drier to the screens.

HOT-MIX ASPHALTIC CONCRETE - Asphaltic concrete in which the aggregates are heated to about 250-325 F and are then mixed with asphalt cement.

HUMUS - A dark brown material formed of partly rotted vegetable or animal matter.

HYDRATED LIME - A fine white powder used in mortar for brickwork or for treating soil. To make it, limestone is heated to a high temperature, allowed to cool, and slaked with water. The lime putty so formed is dried and powdered before shipment.

HYDRATION - The process by which cement combines with water to form gel.

IDENTIFY - To make sure of the nature or source of a material.

IMPURITIES - Materials found in an aggregate that weaken the concrete in which the aggregate is used.

IMPERVIOUS MATERIAL - A material, such as glass, that will not allow water or water vapor to pass freely.

INITIAL SET - The condition of concrete or mortar when it has hardened just enough to retain its shape without side support.

INSERTS - Metal devices put in a concrete member during casting to provide means for fastening other parts to the member later.

INTERLOCKING - Fitting together, like pieces of a jig-saw puzzle, so that the particles are not easily moved.

INTERNAL FRICTION - The resistance to movement of soil or aggregate particles over each other, caused by roughness of the surfaces of the particles and their shape and size.

INVERTED CHOKE - A layer of stone screenings, usually having a depth of about 1 inch, spread on a subgrade or subbase before stone for macadam construction is placed.

INVERTED EMULSION - A liquid formed by suspending a small amount of water (usually about 6% by weight) in the form of very small droplets in an asphalt cut-back by the use of an emulsifying agent.

ISOLATED - Set apart or separated so as to be alone.

JACK - An adjustable device for holding up forms, used where it is desired to lower the forms gradually during the removal operation.

JOB MIX FORMULA - The aggregate gradation and bitumen content specified for a bituminous paving mixture. A specified mixing temperature is usually considered to be a part of the job mix formula.

JOB MIX TOLERANCES - Maximum plus and minus percentages, set by the Specifications, by which the gradation of the aggregates and the bitumen content of the mixture can vary during the production of a bituminous paving mixture. The maximum number of degrees by which the temperature of the completed mixture can vary, above or below that established by the Engineer, is usually considered part of the job mix tolerance.

JOINT - A narrow space separating two slabs or sections of pavement. A transverse construction joint across a concrete pavement allows the concrete to shrink without cracking. A transverse expansion joint provides room for an increase in length in hot weather. A longitudinal joint, or one lengthwise of the roadway, allows the pavement edges to move without cracking the concrete.

JOINT SEALER - A compound for preventing the entrance of water and solid particles into a joint. The compound is usually melted and then poured into the joint.

KEY; KEYING - To fasten together by wedging.

KEYWAY - A low projection or shallow groove at a construction joint in concrete.

KIEL - A large crayon, usually yellow, blue, or red, used for making temporary marks on stakes or other surfaces during construction.

KILN-DRIED LUMBER - Wood from which practically all moisture has been removed by heating under controlled conditions.

LAITANCE - A weak, soupy mortar that collects at the top of a deep layer of freshly placed concrete when too much mixing water has been used.

LATERAL DRAINS - Branch drains that carry water from beneath the pavement to other drains at the sides of the road.

LAYOUT STAKES - Wooden stakes, driven with their tops at or near the ground surface, to mark the positions of important points.

LEADS - The parts of a pile drive that guide the pile and hammer while the pile is being driven.

LEAN - A bituminous paving mixture is said to be lean if it contains less bitumen than usual for like mixtures.

LEDGE - A projecting ridge of rock.

LEVELING COURSE - The course constructed immediately on top of the base, or existing pavement, for the purpose of removing sags below a planned grade before an overlying course is placed. A binder course may act as a leveling course and may then be called a binder-leveling course.

LIFT - A spread and compacted layer of concrete in a form.

A spread and compacted layer of soil in a fill or embankment.

LIME - See AGGRICULTURAL LIME, HYDRATED LIME, and POZZOLAN.

LIMESTONE FILLER - A standard commercial filler material, used in bituminous mixtures, made by grinding lime rock to a powder all of which will pass through a No. 100 sieve. See FILLER.

LOESS - Wind-blown silt or silty clay.

LONGITUDINAL - Running or placed lengthwise.

LONGITUDINAL FINISHER - A machine that causes a metal float, about 12 feet long, to pass back and forth across the paving lane during its construction. The float is held parallel to the forms and passes across the concrete with a sawing motion as the machine moves ahead.

LONGITUDINAL JOINT - A joint which extends lengthwise of the roadway. In bituminous pavement, the joining of the lanes of paving material.

LONGITUDINAL KEYS; DOWEL SHIELDS - Plates of thin metal shaped and placed to form a key, or tongue-and-groove joint, between pavement slabs. The key so formed is usually about 2-1/2 inches high and 1 inch deep.

LUTE - A hand tool used to smooth the surface of a pavement during construction. It is made like a rake but has a smooth straight bottom edge instead of teeth or tines.

MACADAM - A layer of coarse, graded, angular mineral aggregate with a filler of fine aggregate, in which interlocking is obtained by compaction.

MANDREL - A temporary pile, used to place thin steel shells for the construction of cast-in-place concrete piles. A type of mandrel is also used to construct vertical sand drains.

MANUAL CONTROL - Operation of a machine or paving plant by hand adjustment of the regulating devices.

MAP CRACKING - A form of cracking of either portland cement concrete or bituminous pavement where the cracks form a pattern that looks like the boundaries shown on a map.

MARKET VALUE - The highest price for which property can be sold in the open market by a willing seller to a willing purchaser, neither acting under compulsion and both exercising reasonable judgment.

MASONRY PLATE - A steel bearing plate securely fastened to the concrete support for a bridge.

MASS CONCRETE - Concrete with no steel reinforcement.

MAT - The partially compacted course of bituminous paving material laid by a bituminous paver-finisher.

MEAN EFFECTIVE PRESSURE - The average pressure on the ram of a pile hammer driven by steam or compressed air.

MECHANICAL ANALYSIS - Finding the gradation of an aggregate by the use of specified sieves. Same as sieve analysis or gradation test.

MEDIAN - The portion of a divided highway separating the traveled ways for traffic in opposite directions.

MESH - A fabric composed of steel wires welded together at their intersections (also known as welded wire fabric).

MICA - A mineral in which two layers of one material are separated by a layer of another material. The layers separate easily into sheets or flakes.

MIXING TIME - The period of time during which all materials for concrete are in the revolving drum of the mixer.

MIXTURE - In bituminous paving practice, the completed paving material.

MODULUS OF RUPTURE - A measure of the strength of concrete when it is broken by bending. The higher the modulus of rupture, the greater the strength of the concrete. Hardened concrete usually has a modulus of rupture of 300 to 900 psi, the strength depending mostly on the age of the concrete, the amount of cement, and the type of aggregate used in the concrete mixture.

MOISTURE CONTENT - The proportion of moisture in any material, expressed as a percent of the dry weight. If 10.5 pounds of damp sand weighed 10.0 pounds when dry, the moisture content is 0.5 divided by 10, times 100, or 5 percent.

MOISTURE-DENSITY RELATIONSHIP - The effect of moisture content on the density of a soil compacted under certain conditions.

MONUMENT - A permanent reference point. Examples are an iron pipe or bar driven in the ground; a concrete or stone post with a cross, drill hole, or metal plug in the top; or a metal marker set in concrete at or below the ground surface.

MORTAR - In cement concrete, the mixture of cement, sand (fine aggregate), and water that fills the spaces between the particles of coarse aggregate and binds them

together. A 1:2 mortar, made of one volume of cement and two volumes of sand mixed with enough water to produce a stiff paste, is used for patching rough areas, called honeycomb, sometimes found in the sides of a concrete pavement slab when the forms are removed.

In bituminous concrete, the mixture of bitumen, fine aggregate particles, and filler that fills the spaces between the larger particles and binds them together.

MUCK - Mud rich in material resulting from the rotting of plant growth. Usually black or dark in color.

MUD - Any fine soil containing enough water to make it soft.

NAPHTHA - An inflammable liquid, very much like gasoline, produced from petroleum.

Solvent naphtha is produced by distilling such materials as coal tar, coal, and wood.

NOSE CAP - A short tube, closed at one end, placed on one end of a dowel in an expansion joint to provide space for movement of the dowel in the hardened concrete. There must be a stop in the tube to prevent it from being pushed all the way on to the dowel before the concrete hardens.

OFFSET CASTINGS (FENCING) - Pieces of cast metal used to hold in place the wire ropes of guard fences.

OFFSET STAKES - Stakes that are located a measured distance from the centerline of a roadway. They are usually placed so that they will be outside the construction area, where they will not be disturbed or destroyed by construction equipment.

OPEN-GRADED AGGREGATE - A well-graded aggregate that contains little or no fines and has a high percentage of aggregate voids.

OPEN MIX - A mixture with not enough fine aggregates, so that there is a high percentage of voids in the completed pavement.

OPTIMUM - The best quantity, number, or condition.

OPTIMUM MOISTURE CONTENT - The percent of moisture at which a particular soil will have the greatest density obtainable with a specified method of compaction.

OVERBURDEN - Soil or rock lying on top of another material.

OVERDRIVING - Continued driving of a pile after it has been driven to refusal, or nearly so. Continued overdriving may damage a pile seriously.

OVERHAUL -The extra hauling distance when material from a grading section is hauled outside that section.

OVERLOAD - To load an aggregate screen beyond its capacity. See OVERRUN.

OVERRUN; CARRY-OVER - When a screen is overloaded with too thick a layer of aggregate, some particles finer than the openings in that screen will ride on the surface of the layer and will not drop through the screen. Such particles will "overrun" or be carried over into a bin which should contain only larger particles.

PADDLE FLOAT - A hand tool, usually made of wood, used to smooth the surface of newly placed concrete.

PARALLEL - Having the same direction. Parallel lines are the same distance apart at all points.

PARAPET - A wall alongside the deck of a bridge.

PAVEMENT STRUCTURE - The combination of subbase, base course, and surface course placed on a subgrade to support the traffic load and distribute it over the subgrade.

PAVING - Covering a road or other surface with a specified material such as concrete or an asphaltic mixture.

PEAT - A light, soft swamp soil consisting mostly of rotted plant growth.

PENETRATION - The vertical distance a pile moves as it is being driven into the ground.

PERCENT VOIDS FILLED WITH ASPHALT - The ratio, reported as a percentage, of the volume percentage of bitumen in a bituminous mixture to the volume percentage of aggregate voids in the mixture.

PERMEABILITY - The ease with which a porous material conducts a fluid.

PERVIOUS; PERMEABLE - Allowing water to pass freely. A mass of crushed stone, which has spaces between the particles through which water can flow easily, is a very pervious material.

PHYSICAL TEST - A test made to find a physical property of a material, such as weight per cubic foot or compressive strength.

PIER - A support for a bridge at some point between the end abutments.

PIGMENT - The fine particles that form the coloring material in paint.

PILES - Vertical or nearly vertical members, embedded partly or entirely in the ground, used to provide support for a structure where the ground is not firm enough.

PIPE SHELL - A thin metal casing used to form a cast-in-place concrete pile.

PIPE SLEEVES - Openings made in a concrete slab or wall by placing short sections of pipe in the forms before they are filled with concrete.

PIT - The area between the pavement forms where freshly mixed concrete is placed on the subgrade.

PLAIN CONCRETE - Concrete with no steel reinforcement.

PLAIN STRUCTURAL STEEL - Rolled steel shapes that have not been formed into dimensioned structural members.

PLANT-MIXED SURFACING - A designed combination of mineral aggregate and bituminous material mixed in a central plant.

PLASTIC - The condition of concrete when it will flow rather easily and can be readily placed in the forms.

The property of a compacted bituminous mixture which permits its shape to be easily changed without cracking or breaking.

PLATE SPRING BRACKETS - Metal stampings formed to hold in place the wire ropes of guard fences.

PLYWOOD - A material made by gluing together two or more thin layers of wood to form fairly large sheets.

POINT - To fill the outside part of a joint or hole in masonry with dense mortar.

PONDING - Collection of water in shallow pools.

POUR - The concrete placed in a structure between construction joints.

PORE PRESSURE - Pressure on water in the spaces between soil particles caused by compressive forces such as the weight of overlying fill.

POROUS - Full of small spaces through which water can pass easily.

POST CONSOLIDATION - A term describing the compaction of a pavement course by traffic to a density higher than that at the completion of construction.

PORTLAND CEMENT - A powdered mixture of materials containing clay and limestone. The raw materials are mixed in the right proportions, and the mixture is processed so that the powder will have the desired properties.

PORTLAND CEMENT CONCRETE - See CONCRETE.

POT-HOLE - A shallow hole extending below the road surface.

POWER HAMMER - A pile hammer driven by the action of steam or compressed air.

POZZOLAN - A combination of hydrated lime and a powdery material, usually flyash, which forms a cementing material when moist.

PRECISE - A rifle is precise when it will place all bullets within a small space on the target.

PREMOLDED EXPANSION-JOINT MATERIAL - A compressible material shaped to form a joint of specified width.

PRESTRESSED CONCRETE - Reinforced concrete in which the concrete is compressed before service loads are applied so that it can support greater loads than ordinary reinforced concrete without cracking. In pretensioned concrete, the steel bars, wires, or cables are held in a stretched condition during placing of the plastic concrete and until the concrete has hardened. When the pull on the reinforcing steel is released, the concrete is compressed.

In posttensioned concrete, the reinforcing steel is stretched after the concrete has hardened. The steel is then clamped at the ends in such a way that, when the pull is released, the concrete is compressed. Members of prestressed concrete are usually made in a casting yard and shipped to the job.

PRIME COAT; PRIMING - The first application of a bituminous material to an existing absorbent surface. Priming plugs small holes or voids in that surface, coats and binds dust and coarse aggregate particles, hardens or toughens the surface, and increases adhesion between the surface and the bituminous course constructed upon it.

PROFILE - A line on a drawing which shows elevations of points along a selected route. A profile usually shows both ground elevations and grade-line elevations.

PROPORTIONING - Combining definite amounts of materials to form a mixture.

PROPORTIONING CONCRETE - Determining the amounts of fine aggregate, coarse aggregate, and water to be used with each bag of cement in concrete.

PUGMILL - A type of mixer used for mixing bituminous paving materials. The metal container, or box, which has a capacity of from 1 to 3 tons, is open at the top, and is jacketed for heating with steam or hot oil. In a batch pugmill, the box has a sliding gate at the bottom an contains two shafts that rotate in opposite directions. Each shaft is fitted with arms equally spaced around and along the shaft. At the end of each arm, a paddle is attached at an angle. The preferred arrangement is usually to have the paddles set so that, when the shafts are rotating with the tips of all paddles rising in the center, the paddles have an auger-like motion and the material being mixed is moved in one direction along one side of the box and in the opposite direction along the other side. A continuous pugmill is similar, but the material enters the box at one end and leaves from the other end. Pugmills used for soil mixtures are usually of the continuous type and are not steam jacketed.

PUMPING - The forcing out of foundation material, either wet or dry, through joints or cracks or along edges of rigid slabs, as a result of vertical movements of the slab under traffic.

PYROMETER - An instrument that shows, on a dial or scale, the temperature of the aggregates as they leave the drier.

QUARRY - A place from which stone is excavated, as by cutting or blasting, for construction purposes.

QUARTERING; QUARTERED - A method of reducing the volume of a sample to testing size. The material is mixed and formed into a cone, and the cone is then flattened and separated cleanly into four parts. Two opposite parts are removed, the remaining material is remixed, and the quartering process is repeated until the remaining quarters are of the desired size.

QUICKSAND - Fine sand or silt that is prevented from settling firmly together by upward movement of water.

RADICAL - Extreme. A large change in a property of a material.

RANDOM - Without aim or reason, depending entirely on chance.

RAVELING - Continued loss of aggregate from a bituminous pavement from the surface downward, or from the edges inward, caused by the action of traffic.

RE-BARS; REINFORCING BARS - Steel bars used as reinforcement in concrete.

RED DOG - Burned refuse from coal mines which has a reddish color.

RED SEAL - A red tag or poster placed on a tank or drum of material that may take fire easily.

REFINERY - A plant for producing petroleum products, including asphalt, from crude petroleum oil.

REFLECTION CRACKS - Cracks which develop in bituminous surfacing (overlays) over concrete or soil-cement courses above joints and cracks.

REINFORCED CONCRETE - Concrete in which steel reinforcement is embedded so that the steel and concrete act together in resisting stress.

REINFORCING STEEL - Steel bars, rods, or wires placed in concrete to prevent cracking.

RESTRAINT CRACKS - Cracks in concrete pavement which start near the outside edges (within 3 feet of an edge) and run toward the longitudinal joints.

RESURFACING - An additional or replacement surface placed on an existing pavement to improve its riding qualities or increase its strength.

RETAINING WALL - A wall built to hold back earth or loose rock, so that the material behind the wall will not slide or cave in.

RICH - A bituminous paving mixture is said to be rich if it contains more bitumen than usual for like mixtures.

RIFFLING - A method of reducing the volume of a sample to testing size. The sample is poured into the hopper of a riffle. Chutes in the riffle divide the sample into two equal parts, and each part is directed into a separate pan. The contents of one pan are thrown away, and the contents of the other are poured into the riffle hopper. The process is repeated until one pan contains the right amount of material.

RIGHT OF ACCESS - The right to enter or leave a highway from bordering land.

RIGHT-OF-WAY - A general term describing land or property, usually in a strip, obtained for or given over to a highway.

RIGID BASE - A base that has a high resistance to bending and distributes loads to the foundation over a large area.

RIGID PAVEMENT - A pavement which has a high bending resistance and distributes loads to the foundation over a large area. Examples are portland cement concrete pavements and bituminous, brick, or stone block pavements supported on a portland cement concrete base.

RIVET - A short, cylinder-shaped piece of metal used to fasten together two or more pieces of steel in a structure. One end of a rivet has a preformed head, and the head at the other end is formed with a hammer as the rivet is driven.

ROADBED - The graded portion of a highway, usually considered as the area between the intersections of the subgrade surface and the side slopes, upon which the base course, surface course, shoulders, and median are constructed.

ROAD-OIL - A liquid asphaltic oil used to lay the dust on earth roads.

ROAD-MIXED SURFACING - A designed combination of materials used for construction of a flexible pavement mixed on a roadbed or in a traveling plant.

ROADWAY - The portion of a highway within limits of construction.

ROCK - In relation to the construction of embankment, rock is any type of stone such as limestone or sandstone, boulders, or old concrete or brick, provided that there is not enough fine material to fill all the voids between the rock pieces and that these pieces cannot be readily incorporated in an 8-inch loose layer.

ROCKER - A type of steel support used (usually at the expansion end of a bridge) to permit the structure to move in the direction of the span.

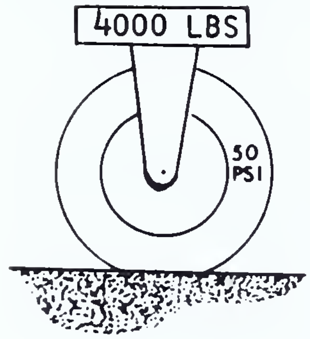
ROLLERS - Steel cylinders or parts of cylinders used (usually at the expansion end of a bridge) to provide support so that the structure can move in the direction of the span.

RUBBER COMPOUNDS - Bituminous materials mixed with a small amount of rubber and used for filling and sealing joints and cracks.

RUBBERIZED SEALING MATERIAL - A joint-sealing compound containing rubber.

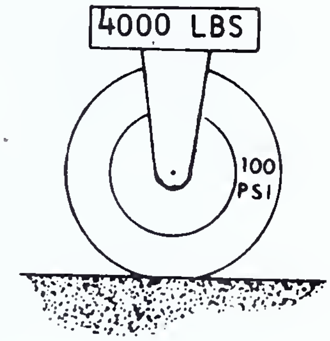
RUBBER-TIRED ROLLER - A frame supported by wheels having rubber tires inflated with air. The wheels are usually mounted on two axles in tandem and line up so that the tracks of the rear tires more than cover the spaces between the front-tire tracks. By adding weight or ballast to the roller and by changing the tire pressure, the contact pressure, or the pressure of the tire on a unit area of the rolled surface, can be adjusted to best compact a particular material.

750 x 15 Compactor Tire



Area=63.7 Sq.Inches

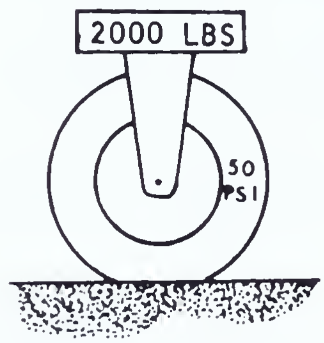
Contact Pressure
4000/63.7 = 62.8



Area=45.9 Sq.Inches

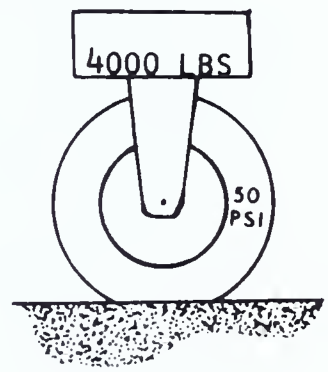
Contact Pressure
4000/45.9 = 87.1

750 x 15 Compactor Tire



Area=35.4 Sq.Inches

Contact Pressure
2000/35.4 = 56.5



Area=63.7 Sq.Inches

Contact Pressure
4000/63.7 = 62.8

The total weight or the wheel load of a rubber tired roller does not, by itself, have much effect on how well it compacts a material. The pressure that forces the particles of material together, called the ground pressure or contact pressure, depends on the wheel loads, the inflation pressure, and the contact area.

SALAMANDER - A device without a vent or chimney connection in which fuel is burned to provide heat in cold weather.

SAMPLE SPLITTER - A riffle (See RIFFLING).

SAND - Pieces of stone from about 1/64 to 1/8 inch in diameter. Natural sand is taken from pits and usually has rounded particles. Manufactured sand is made by crushing rock, gravel, or slag and the particles have sharp edges.

SAND ASPHALT - A mixture of sand and asphalt, either plant mixed or road mixed.

SAND BOXES - Boxes that contain dry sand and which are used to support forms. The weight of the forms rests on the sand. A hole in the box can be opened to permit the sand to run out slowly so that the forms are lowered gradually.

SAND OR GRAVEL BANK - A long mound or heap of ground containing mostly granular material.

SCALING - The peeling off of a thin layer of concrete from the finished surface of a pavement.

SCALPING - The removal of a thin layer of soil, usually containing root growth, from the ground surface.

SCRATCH OR WEDGE COURSE - A course, separate and distinct from the binder course, placed on the base to change the crown or to adjust the grade or superelevation.

SCREED - A long piece of wood or metal moved across the surface of newly placed concrete with a sawing motion to consolidate the concrete and to smooth the surface.

On a paver-finisher, the lower face of the screed unit which shapes and partially compacts the mat of bituminous material.

SCREED UNIT - The assembly, towed by the tractor unit of a paver-finisher, which places, strikes-off, levels, and partially compacts bituminous paving material to form a lane of a course of pavement.

SCREEN - Sections of heavy wire mesh, having openings from about 2 inches to 1/8 inch square, placed over the hot bins of a paving plant to separate the aggregates into various sizes before they are proportioned into bituminous mixtures.

SCREENINGS - The fine aggregate and dust screened from crushed stone.

SCUPPER DITCHES - Ditches, placed in a berm or shoulder, which conduct water to inlets or sluiceways for flow down a slope.

SEAL COAT - A covering, consisting of a single application of asphalt binder followed by a single application of aggregate, placed on an existing bituminous surface.

SEAL NUMBER - Numbers raised from the metal strip used for sealing railroad cars.

SEASONED LUMBER - Wood which has been partially dried so that it will not shrink any more but still retains enough moisture to prevent rapid decay.

SEEPAGE - The escape of water through the soil, or water flowing from a fairly large area of soil instead of from one spot as in the case of a spring.

SEGREGATE; SEGREGATION - Separation of portions of a mixture from the mass. In a stockpile consisting of a mixture of large particles of aggregate and small particles, some of the large particles tend to segregate by separating from the combination. In concrete, segregation occurs if some of the coarse aggregate separates from the combination of coarse aggregate, fine aggregate, cement, and water while the freshly mixed concrete is being moved or placed.

SELECTED MATERIAL - Suitable native material obtained from roadway cuts or borrow areas or other similar material, used for subbase, roadbed material, shoulder surfacing, slope cover, or any other specified purpose.

SET - The hardening of a mixture of portland cement and water, cement mortar, or concrete.

SETTING UP - The process by which the cement in freshly mixed concrete or mortar combines with water and hardens (sets up).

SETTLEMENT - The downward movement of a structure or a short section of pavement due to its own weight, to the loads which it supports, or to shrinkage of the supporting soil.

SET-UP - A term used to describe the adjustment of bituminous paving material at a joint, by a raker using a lute, so that the pavement at this point will have the proper elevation, appearance, and density after rolling.

SHEAR CONNECTORS - Devices for keeping one member of a structure from sliding on another. Projections or spiraled rods on the top of a bridge beam form shear connectors that fasten the concrete bridge slab in place.

SHEATHING; SHEETING - Boards or plywood used as forms for the sides of a wall or the bottom of a floor slab.

SHEEP'S-FOOT ROLLER; TAMPING ROLLER - A cylindrical roller having lugs with "feet" forming the outer tips of the lugs.

SHEET ASPHALT PAVEMENT - A very dense, high-type surface made of sand, mineral filler, and asphalt cement. Used as a surface on city streets.

SHEET ASPHALT SURFACING - A designed mixture of well-graded sand, mineral filler (10-20%), and asphalt cement (9.5-12%) processed in a central plant and laid and compacted while hot.

SHIPLAP - Sheeting made of boards cut and set so that an edge of one laps over the next.

SHOULDER - The graded part of a road on each side of the pavement.

SHOVING - Displacement of bituminous paving material due to the action of traffic, generally resulting in the bulging of the surface.

SIDE SLOPE - A sloping side of an embankment or cut.

SILT- A type of soil made up of small particles somewhat larger than those in clay. When wet, silt is soft but not as sticky as clay. Lumps of dry silt can be broken in the fingers and fall apart when placed in water.

SKEW; SKEWED - At an angle other than a right angle. The centerline of a skew bridge or culvert is not at right angles to the centerline of the stream over which it crosses.

SKEW ANGLE - The complement of the acute angle between two centerlines which cross.

SKIN FRICTION - Friction between the outside surface (skin) of a pile and the surrounding soil. Skin friction resists movement of the pile in the soil.

SKIP GRADED AGGREGATE - Aggregate having little or no material of one or more particle sizes.

SLAB BOLSTER - A device used to hold steel bars the right distance above the forms for the bottom of a floor slab.

SLAB SPACER - A device used for holding steel bars at the right distance above the forms for the bottom of a floor slab.

SLOPE - An inclined surface.

SLOPE LINES - Straight inclined lines connecting the original ground surface with the edges of the surface of a cut or embankment at the finished grade.

SLOPE STAKE - A stake marking the point where a slope line in a cut or fill meets the original ground surface.

SLOPE WALL - A pavement constructed on the side slope of an excavation or embankment, to prevent water from washing away the soil on the slope.

SLUMP - The measure of the consistency of concrete determined by placing the concrete in a slump cone, removing the cone, and allowing the concrete to settle under its own weight. The slump is the distance the top of the concrete settles from its original position. Concrete used in the construction of pavement must have a slump between 1 and 2-1/2 inches.

SOIL - The loose material of the earth's surface of which at least 35 percent will pass the No. 200 sieve.

SPACING - The distance between centers of reinforcing bars or wires.

SPADE; SPADING - A thin metal tool, with a long handle, that is slid between freshly placed concrete and a form. Spading pushes particles of coarse aggregate back from the form and allows air to escape so that a smooth surface is seen when the forms are stripped.

SPALL - A chip of concrete broken from the surface of a concrete pavement, usually next to a joint, or from a concrete member or concrete pipe.

SPAN - The width of the opening at a bridge or a culvert.

SPECIFIC - Specified or particular.

SPECIFICATIONS - The directions, provisions, and requirements contained in the Pennsylvania Department of Highways Form 408. The Specifications also include bulletins referred to in Form 408, Drawings, cross sections, applicable Standard Drawings, and any supplements, bulletins, special provisions, or special requirements referred to in or bound with the proposal. All written agreements pertaining to the method and manner of performing the work, or to the quantities and qualities of materials to be furnished under the contract become part of the Specifications.

SPELTER - The zinc coating used for rustproofing iron or steel by galvanizing.

SPILLWAY - A paved channel for leading water from the top of a slope of an excavation to a nearby outlet, to prevent the water from washing away the soil on the slope.

SPLICE - A connection made between two parts of a structural member so as to increase the length of the member.

SPOIL - Soil or rock removed from its original location and wasted.

SPOIL BANK - A narrow pile of material, such as the earth dug from a trench.

SPRINGING LINES - The lines at the junctions of the main part of an arch and its supports (abutments).

SPUD VIBRATOR - A type of vibrator used for consolidating concrete. A weight that is slightly off balance is rotated at high speed inside a round steel shell, usually about 2 inches in diameter and 18 inches long. The off-balance weight is rotated by a flexible shaft connected to an engine or motor. When the spud, made up of the rotating weight and the outside shell, is placed in newly mixed concrete, the mixture for a distance of about 18 inches around the spud is made more liquid so that the concrete settles into place and the large air bubbles rise to the top and escape.

STABLE - Firm or unchanging. Describes a soil or material that will support a heavy load without movement.

STABILITY - The property of a compacted paving mixture to resist change of shape when force is applied.

STABILIZATION - Changing the quality of soil or aggregate by mixing with it material that will increase its load-bearing capacity, firmness, and resistance to weathering or displacement.

STAGGER - To arrange joints so that a joint in one row of parts is opposite a point between joints in the next row of parts.

STANDARD DRAWINGS - Drawings which are not shown or called for on the Construction Plans. These drawings show typical details of construction for such items as roadway reinforcement, drainage, guard fence, and retaining walls.

STATION - Any one of a series of stakes placed a measured distance from the point of beginning, or the corresponding points on a drawing or map.

STEEL BEAM PILES - Piles made of structural steel, usually formed into "H" sections.

STEEL PIPE PILES - Sections of steel pipe driven into the ground and usually filled with concrete.

STEEL REINFORCEMENT - Steel bars, mesh, or wires embedded in concrete to help resist stresses.

STEEL SHAPES - Rolled steel members with various standard cross sections. Wide-flange sections, I beams, channels, and angles are standard structural steel shapes.

STIRRUP - A steel bar in a reinforced concrete beam. The bar usually is bent in the form of a U and helps resist so-called diagonal tension stresses.

STOCKPILE - Piles of materials stored for later use.

STONE-FILLED SAND ASPHALT - A paving mixture of coarse aggregate (less than 40 percent), fine aggregate, filler, and asphalt cement.

STONE SCREENINGS - Dust and small particles of aggregate screened from stone after crushing.

STORM SEWER - A large pipe or small structure used to carry to an outlet the water collected by surface drainage.

STRAND - A group of steel wires twisted together to form a unit.

STRATUM - A layer of material in its natural position in the ground. The plural of stratum is strata.

STRETCHER - A piece of masonry laid in a wall lengthwise (parallel to the direction of the wall).

STRIKE WEDGES - Wooden wedges that hold centering for an arch firmly in position until the concrete is placed. When they are knocked out, they allow the centering to be lowered gradually.

STRINGER - A bridge floor member that is parallel to the bridge centerline.

STRIP - To remove forms from concrete that has hardened.

STRUCTURAL PURPOSES - Used to form part of a structure. Lime used for structural purposes forms part of the mortar joining bricks or masonry units.

STRUCTURAL STEEL - Steel members such as I beams and channels, which support the loads on a structure.

STRUCTURE - Anything constructed or built. Examples are buildings, bridges, pipe lines, and fences.

STUDS - Vertical pieces of wood which help hold sheathing for forms in place.

SUBBASE - A layer of specified or selected material of planned thickness that is placed on the subgrade and compacted to form a surface on which a concrete pavement or a base for flexible pavement is constructed.

SUBGRADE - The upper part or top surface of a roadbed upon which the pavement structure and shoulders are constructed. In earthwork, it is the bottom of an excavation or the top of an embankment between the outer limits of pavement, base course, or subbase. In connection with concrete paving operations, subgrade means the surface of the material on which the pavement is constructed, usually a granular subbase.

SUBGRADE TREATMENT - Stabilization of roadbed material.

SUBSTRUCTURE - The foundations of a bridge and other parts of the piers and abutments below the level of the end supports.

SUPERELEVATE - To slope the surface of a pavement upward toward the outside edge of a roadway on a horizontal curve.

SUPERELEVATION - The difference in elevation between the inside and outside edges of a roadway on a horizontal curve.

SUPERSTRUCTURE - The parts of a bridge above the level of the end supports.

SURFACE COURSE - One or more layers of a pavement structure designed to take care of the traffic load. The top layer which resists skidding, traffic wear, and weathering.

SURFACE MOISTURE - That part of the moisture content of aggregate which has not soaked into the particles.

SURFACE TREATMENT - A covering, consisting of an asphalt binder followed by a single application of aggregate, placed on a prepared gravel or crushed-stone base.

SWEAT - Aggregate is said to "sweat" when the particles give off water vapor which changes into moisture droplets that can be seen.

SWELL - To rise because of wetting. A soil mixture containing clay or silt may expand from the volume in a compacted condition when it becomes wet. If the subgrade on which a concrete pavement is to be built swells, the surface of the subbase may rise between the forms. If this swelling is not corrected, it will result in a thin pavement.

TACK COAT - A very thin application of liquid bituminous material sprayed on a bituminous surface or an existing pavement.

TAMPER - A tool for compacting soil in spots which cannot be reached by rollers.

TAMPER BAR - A heavy steel plate, with an angled face at the bottom, that travels up and down about 1/8 inch just ahead of the screed on some types of paver-finishers. In the down position the plate extends about 1/64 inch below the lower face of the screed.

TANDEM ROLLER - A roller that has two or three rolls (smooth steel drums) in line in the direction of travel. One with three rolls is sometimes called an axle tandem.

TAR - (See COAL TAR).

TENSION; TENSILE STRESS - The stress produced in a member when the forces acting on it tend to pull the member apart.

TEXTURE - The grain of the surface of a bituminous pavement resulting from the shape, size, and arrangement of the particles.

THIN AND ELONGATED PIECES - Particles of aggregate retained on a 1-inch sieve and so shaped that the greatest thickness or depth is less than one-fourth of the greatest dimension.

THREE-WHEELED ROLLER - A steel roller with two large, narrow rear wheels and a smaller, wider, front steering wheel.

THRUST - Pressure against another pavement slab or a structure caused by the expansion of concrete pavement.

TIE-BARS; DOWELS FOR LONGITUDINAL JOINTS - Bars of reinforcing steel (#5 x 4 feet) placed across longitudinal joints of concrete pavement near the middle of the depth of the pavement. These bars tie the slabs together and hold the joint closed.

TIES (METAL) - Small steel rods that hold the forms for a concrete wall the right distance apart.

TILL - The mixture of rock fragments and fine materials left by melting glaciers.

TIP - The lower end of a pile.

TOE - The line where the side slope of an embankment meets the original ground.

TONGUE-AND-GROOVE - A type of joint between boards, each of which has a projection on one edge and a corresponding depression on the other edge.

TOPSOIL - A soft, easily worked soil, reasonably free from subsoil, clay lumps, brush, roots, weeds, stones larger than 2 inches, litter and other material unsuitable or harmful to plant growth.

TRAFFIC-BOUND - A term describing the compaction of road materials by traffic.

TRAFFIC LANE - The portion of the traveled way for the movement of a single line of vehicles.

TRANSVERSE - Anything which runs or is placed across the road at, or nearly at, right angles to the centerline.

TREE WALL - A wall built around a valuable tree, shrub, or other woody plant in a side slope of an embankment to prevent the soil from burying the roots too deeply.

TRENCH - A long narrow excavation.

TREMIE - A pipe, open at the top and bottom, used to drop fresh concrete vertically without segregation. Usually used for placing concrete in water.

TRIAL MIX - A concrete mixture designed by the contractor using the materials he intends to furnish for the construction of the concrete pavement.

"TURN OF THE NUT" METHOD - The method of tightening high-strength structural (A325) bolts to the required minimum tension, after the parts have been drawn together tightly by temporary bolts, by first spinning the nut of each high-strength bolt to a snug tight condition, and then giving a nut on a short bolt an additional 1/2 turn, and a nut on a long bolt an additional 3/4 turn. Short bolts are those 5 inches and under for a diameter of 3/4 or 7/8 inch, and those 8 inches and under for a diameter of 1, 1-1/8, or 1-1/4 inches. The allowable tolerance is 1/4 turn over and nothing under.

TYPE J-1 MATERIAL - A mixture of asphalt cement and about 20 percent by weight of very fine rock dust, used for filling and sealing joints and cracks.

UNDERCUT - To excavate below the planned grade line.

UNDERDRAIN - A ditch filled with porous material, placed beneath the pavement to remove ground water.

UNDERSEALING; SUBSEALING - Pumping a waterproof material under an existing pavement to prevent the upward flow of water or mud and to fill spaces under the pavement.

UNIFORM - Always the same; not changing in any way.

UNIFORMITY BAND - The gradation band, showing the least and greatest permissible percentages passing the specified sieves. This band is plotted by applying the job-mix tolerances to the job-mix formula.

UNIFORMLY GRADED AGGREGATE - A granular material with most of the particles of the same size. A material with about equal amounts of particles of many different sizes is said to be well graded.

UNSTABLE - Not firm enough to offer much resistance to movement.

VEHICLE - The liquid portion of a paint in which the pigment is suspended.

VERTICAL ALIGNMENT - The series of straight lines connected by vertical curves, known as the grade line.

VERTICAL CLEARANCE - The clear vertical distance between the surface of a pavement and an overhead structure.

VERTICAL CURVE- A gradual change in gradient along the centerline of a highway.

VIBRATOR - A device for shaking fresh concrete rapidly so that entrapped air and excess water is released and it settles compactly in place in the forms.

VISIBLE - That which can be seen.

VISUAL INSPECTION - Inspection for defects that can be seen.

VISUALLY - By sight.

VITRIFIED BRICK - Brick that have been heated to a very high temperature in the kiln so that the minerals used to make the brick have been formed into a glasslike material.

VITRIFIED CLAY - A material, like that used in brick, from which pipes for drains are made.

WALERS; WALES - Horizontal members used to help hold sheeting for forms in position.

WARPING - A change in the pavement surface from its original shape. In concrete pavement the changes caused by differences in temperature and moisture content at the surface and bottom of the slab.

WATERPROOFING CEMENT - Asphalt cement (Class WM-1) or coal-tar pitch (Class WM-2) used with waterproofing fabric in the membrane system of waterproofing.

WATERPROOFING FABRIC - Woven cotton cloth waterproofed with either asphalt or coal-tar pitch, used in the membrane system of waterproofing.

WATER PUMPING - The forcing of water from beneath concrete pavement upward through joints or cracks by downward movement of the slabs during the passage of heavy axle loads.

WATER TABLE - The part of the bridge deck between the traffic lane and the curb where water flows to the scuppers or other outlets.

WATER VAPOR - Water in the form of a gas which cannot be seen. Steam is a mixture of water vapor and small water particles.

WEARING COURSE - The top layer of a surface course.

WEDGE - A piece of wood or metal with one edge thicker than the opposite edge.

WEEP HOLES - Holes left in a wall to permit water to flow through the wall.

WELD - Metal added between two steel pieces to hold them together. The weld metal is fused with the main pieces.

WELDED WIRE FABRIC - A mesh made of steel wires welded together at their intersections (also called mesh or wire mesh).

WELLPOINT - A short piece of perforated pipe fitted with a driving or jetting point. The perforations are usually covered with a screen, which will allow water to pass but will keep out solid particles.

WHEEL GUARDS - Raised curbs along a bridge deck which form the outside edges of traffic lanes.

WING WALL - A part of a bridge abutment outside the main body of the structure. Its purpose is to retain the approach fill.

WIRE FABRIC - A flexible mesh of large steel wire, usually galvanized, used for fencing.

WIRE MESH - A network of large wires used as distributed reinforcement in concrete pavement.

WIRE ROPE - A cable made of steel wires twisted together.

WORKABLE - Easily placed and finished.

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